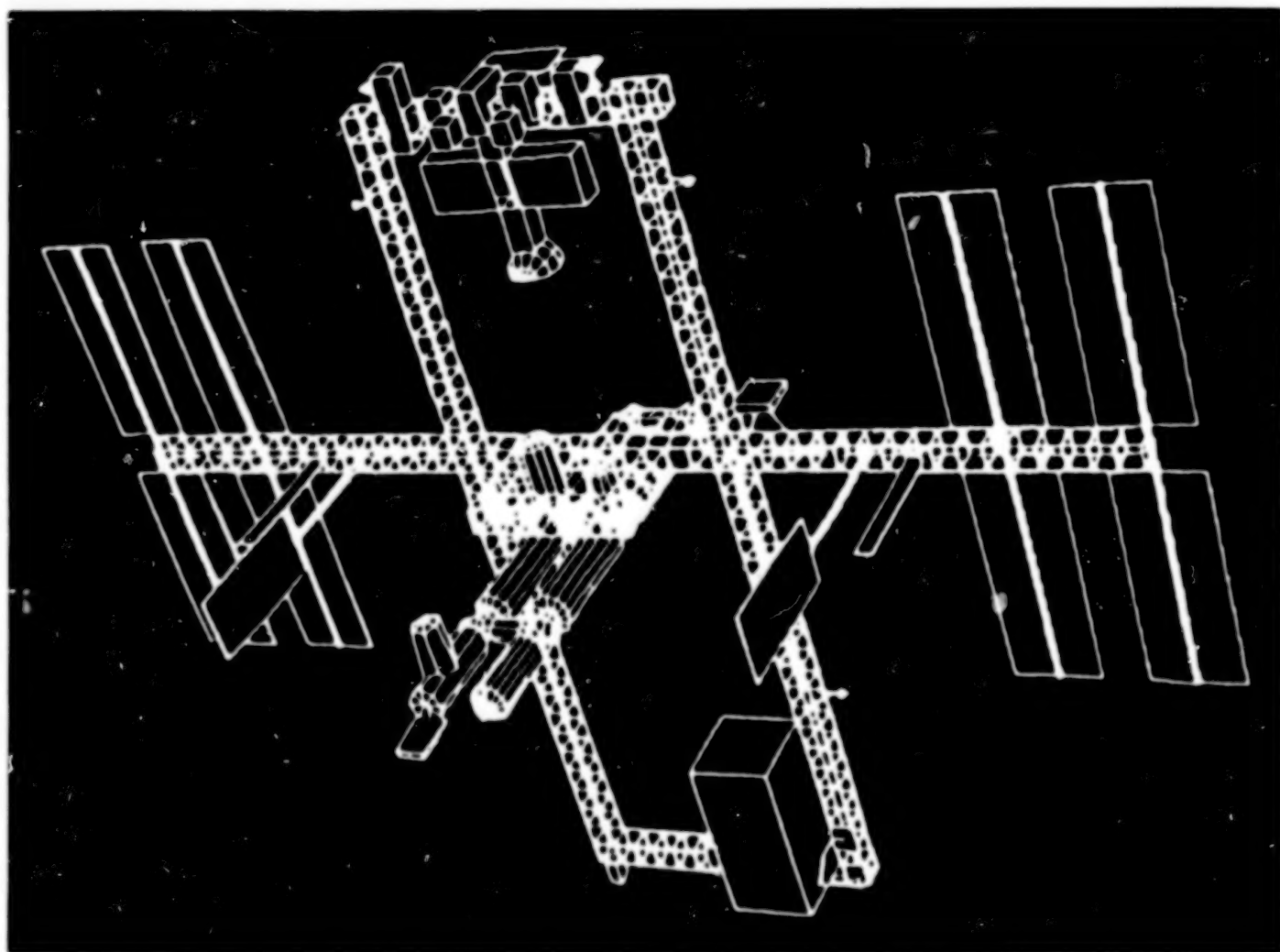




# Space Station Systems

A Bibliography  
with Indexes

NASA SP-7056 (10)  
June 1990



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COMPLETED



# SPACE STATION SYSTEMS

## A BIBLIOGRAPHY WITH INDEXES

### Supplement 10

*Compiled by*  
Technical Library Branch  
and  
*Edited by*  
Space Station Office  
NASA Langley Research Center  
Hampton, Virginia

A selection of annotated references to unclassified reports and journal articles that were introduced into the NASA scientific and technical information system between July 1 and December 31, 1989 in

- *Scientific and Technical Aerospace Reports (STAR)*
- *International Aerospace Abstracts (IAA).*



National Aeronautics and Space Administration  
Office of Management  
Scientific and Technical Information Division  
Washington, DC

1990

NOTE TO AUTHORS OF PROSPECTIVE ENTRIES:

The compilation of this bibliography results from a complete search of the *STAR* and *IAA* files. Many times a report or article is not identified because either the title, abstract, or key words did not contain appropriate words for the search. A number of words are used, but to best insure that your work is included in the bibliography, use the words *Space Station Systems* somewhere in your title or abstract, or include them as a key word.

# INTRODUCTION

This bibliography is designed to be helpful to the researchers, designers, and managers engaged in the design and development of technology, configurations, and procedures that enhance efficiencies of current and future versions of a Space Station.

This literature survey lists 1422 reports, articles and other documents announced between July 1, 1989 and December 31, 1989 in *Scientific and Technical Aerospace Reports (STAR)*, and *International Aerospace Abstracts (IAA)*.

The coverage includes documents that define major systems and subsystems, servicing and support requirements, procedures and operations, and missions for the current and future Space Station. In addition, analytical and experimental techniques and mathematical models required to investigate the different systems/subsystems and conduct trade studies of different configurations, designs, and scenarios are included. A general category completes the list of subjects addressed by this document.

The selected items are grouped into categories as listed in the Table of Contents with notes regarding the scope of each category. These categories were especially selected for this publication and differ from those normally found in *STAR* and *IAA*.

Each entry consists of a standard bibliographic citation accompanied by an abstract, where available, and appears with the original accession numbers from the respective announcement journals.

Under each of the categories, the entries are presented in one of two groups that appear in the following order:

- (1) *IAA* entries identified by accession number series A89-10,000 in ascending accession number order;
- (2) *STAR* entries identified by accession number series N89-10,000 in ascending accession number order.

After the abstract section there are seven indexes—subject, personal author, corporate source, foreign technology, contract number, report number, and accession number.

A companion continuing bibliography, *Technology for Large Space Structures*, is available as NASA SP-7046.

George F. Lawrence, *Space Station Office*  
John J. Ferrainolo, *Technical Library Branch*

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## TYPICAL REPORT CITATION AND ABSTRACT



## TYPICAL JOURNAL ARTICLE CITATION AND ABSTRACT





# SPACE STATION SYSTEMS

*A Bibliography (Suppl. 10)*

JUNE 1990

01

## SYSTEMS

Includes system requirements for proposed missions, mission models, overall conceptual configuration and arrangement studies; systems analyses for future required technology; and identification and description of technology developments and experiments for the elements of a complete Space Station system.

**A89-35236#**

### TO FALL FROM SPACE - PARACHUTES AND THE SPACE PROGRAM

M. J. RAVNITZKY, S. N. PATEL, and R. A. LAWRENCE (Irvine Industries, Inc., Santa Ana, CA) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers, Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 222-232. refs (AIAA PAPER 89-0926) Copyright

Space-related applications for parachutes and deployable decelerators are reviewed. Consideration is given to the role of parachutes in earth orbiting vehicle recovery systems, manned spacecraft terrestrial landing systems, manned spacecraft auxiliary/emergency escape systems, planetary spacecraft descent systems. Other applications include extraterrestrial return spacecraft landing systems, launch vehicle recovery, spacecraft ground deceleration, and space station emergency escape and ferry systems. Specific examples are presented of spacecraft and systems using these parachute applications. R.B.

**A89-45831**

### A VISUAL APPROACH FOR SPACE SYSTEM DESIGNERS

TOMMIE DANIEL (BDM Corp., Albuquerque, NM) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 1260-1267. refs Copyright

This paper discusses computerized tools that may be used by designers as they approach problem solving related to engineering, construction and operations in space. Tools for space system designers, both computer hardware and software, are examined with an emphasis on the directions for improvements in each of the major areas. The current state of the art in CAD/CAM, scientific visualization and image processing is discussed, including a broad overview of the implications of new developments in information processing systems related to space systems design. The general topic of simulation to reduce design prototyping is addressed with a focus on a major space related application area, Finite Element Modeling (FEM). Author

**A89-45833**

### POTENTIAL APPLICATION OF SPACE STATION TECHNOLOGY IN LUNAR BASES AND MANNED MARS MISSIONS

J. M. GARVEY and M. M. MANKAMYER (McDonnell Douglas Astronautics Co., Space Station Div., Huntington Beach, CA) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988.

New York, American Society of Civil Engineers, 1988, p. 1306-1319. refs

Copyright

To meet the goals of its Space Station program, NASA is developing a large set of improved space systems capabilities. In areas such as power generation and distribution, on-board data management, and life support, Station technology will represent a major advance over current systems. Given the substantial investment required to create these capabilities, it is worthwhile to consider other potential uses for them. This paper constitutes an early attempt to assess such follow-on applications, particularly in manned space exploration initiatives such as a lunar base and/or manned Mars expedition. Author

**A89-45828\*#** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

### AERODYNAMIC CHARACTERISTICS OF PROPOSED ASSURED CREW RETURN CAPABILITY (ACRC) CONFIGURATIONS

GEORGE M. WARE, BERNARD SPENCER, JR., and JOHN R. MICOL (NASA, Langley Research Center, Hampton, VA) AIAA, Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989. 12 p. refs (AIAA PAPER 89-2172)

The aerodynamic characteristics of seven reentry configurations suggested as possible candidate vehicles to return crew members from the U.S. Space Station Freedom to earth has been reviewed. The shapes varied from those capable of purely ballistic entry to those capable of gliding entry and from parachute landing to conventional landing. Data were obtained from existing (published and unpublished) sources and from recent wind tunnel tests. The lifting concepts are more versatile and satisfy all the mission requirements. Two of the lifting shapes studied appear promising - a lifting body and a deployable wing concept. The choice of an ACRC concept, however, will be made after all factors involving transportation from earth to orbit and back to earth again have been weighed. Author

**A89-45828\*** Boeing Aerospace Co., Seattle, WA.

### NEAR-TERM NUCLEAR SPACE MISSIONS

DANA G. ANDREWS (Boeing Aerospace, Seattle, WA) (IAF, International Conference on Space Power, Cleveland, OH, June 5-7, 1989) Space Power (ISSN 0951-5089), vol. 8, no. 3, 1989, p. 285-306.

(Contract NAS9-18040)

(IAF PAPER ICOSP89-9-4) Copyright

This paper summarizes the current status of proposed NASA Human Exploration Missions (HEMs) presenting detail with respect to schedule and system features. Using the Lunar exploration and Mars exploration missions as design drivers, new vehicle elements have been configured and optimized to meet proposed mission requirements. Both conventional chemical propulsion and alternative vehicle designs incorporating advanced nuclear propulsion systems are included, and the total mass required in Low Earth Orbit (LEO) is compared for each propulsion system. Author

**A89-48158#**

### RELIABILITY AND MAINTAINABILITY WITHIN THE DYNAMIC SYSTEMS-ENGINEERING PROCESS

MICHAEL J. WISKERCHEN (Stanford University, CA) and R. BRUCE PITTMAN (DYSE Corp., San Jose, CA) AIAA and NASA, Symposium on the Maintainability of Aerospace Systems, Anaheim, CA, July 26, 27, 1989. 9 p.  
(AIAA PAPER 89-5047) Copyright

A dynamic systems-engineering methodology for the development of a long-term, inexpensive, and efficient space operations capability is described. The lessons learned from the application of this methodology to modernize the way that the Space Shuttle is processed at Kennedy Space Center is addressed, emphasizing experience gained in reliability and maintainability. Concepts which are applicable to the upgrading of the U.S. launch and space flight operations capability are presented. The methodology is shown to be equally important to the design and development of the Space Station Freedom. C.D.

#### AB9-48177#

#### A LIFE CYCLE COST EFFECTIVENESS COMPARISON OF SATELLITE REPLACEMENT AND SPACE REPAIR STRATEGIES

JAMES H. SUTTLE (Teclote Research, Inc., Manhattan Beach, CA) AIAA and NASA, Symposium on the Maintainability of Aerospace Systems, Anaheim, CA, July 26, 27, 1989. 12 p.  
(AIAA PAPER 89-5068) Copyright

This paper presents a life cycle cost-effectiveness comparison for satellites which fail in orbit. Concepts of replacement and space repair of the failed satellites are treated parametrically. A work breakdown structure identifies the significant cost elements. Inputs to the comparison methodology consist of satellite, launch vehicle, infrastructure, and operational parameters which allow identification of the preferred replace or repair strategy. Author

#### AB9-48178#

#### OPTIMIZING DESIGN FACTORS AND SUPPORT CONCEPTS TO REDUCE SPACE OPERATIONS COSTS

WILLIAM ROBERTSON, JOHN SLINNEY, THOMAS MISENICK (Dynamics Research Corp., Arlington, VA), and EDWARD TAVARES (U.S. Army, Strategic Defense Command, Arlington, VA) AIAA and NASA, Symposium on the Maintainability of Aerospace Systems, Anaheim, CA, July 26, 27, 1989. 11 p. refs  
(AIAA PAPER 89-5069) Copyright

The design considerations for spacecraft bus and payload subsystems are addressed, emphasizing enhancement of cost-effective spacecraft maintainability through optimized reliability and the application of robotic on-orbit support. Results from top-level analyses addressing life-cycle cost benefits using an on-orbit support infrastructure are presented, and the technological readiness of enabling technologies associated with on-orbit maintenance and servicing is examined. A challenging yet viable near-term alternative where international cooperation could provide significant cost savings from economies of scale is examined. C.D.

AB9-20180\*# Colorado Univ., Boulder. Dept. of Aerospace Engineering.

L1 LIBRATION POINT MANNED SPACE HABITAT Final Report  
MARVIN LUTTGES, STEVE JOHNSON, GARY BANKS, RICHARD JOHNSON, CHRISTIAN MEYER, SCOTT PEPIN, and ROBERT MACELROY 1989 83 p  
(Contract NGT-21-002-080)  
(NASA-CR-184732; NAS 1.26:184732) Avail: NTIS HC A05/MF A01 CSCL 22B

Second generation stations or Manned Space Habitats (MSHs) are discussed for an Earth-Moon libration point and in lunar orbit. The conceptual design of such a station is outlined. Systems and subsystems described reflect anticipation of moderate technology growth. The evolution of the L1 environments is discussed, several selected subsystems are outlined, and how the L1 MSH will complete some of its activities is described. B.G.

AB9-20188# General Accounting Office, Washington, DC.  
SPACE STATION: NASA EFFORTS TO ESTABLISH A

#### DESIGN-TO-LIFE-CYCLE COST PROCESS

May 1988 46 p  
(GAO/NSIAD-88-147) Avail: NTIS HC A03/MF A01

NASA's implementation of actions regarding space station operations cost management is reviewed. Although the definition phase has been completed, NASA is still developing major portions of the operations cost management system described in its Dec. 1985 report, including a cost management policy and cost benchmarks. NASA is currently considering a draft directive to help establish a management system that would systematically consider and assess life cycle cost impacts of design proposals. E.R.

AB9-21021# Systems Science and Software, La Jolla, CA.  
CHARGING POTENTIALS FOR TWO SAMPLE SETS OF SPECTRA FROM DMSP SATELLITES Scientific Report No. 8, Jan. - Feb. 1988

T. G. BARKER Feb. 1988 17 p  
(Contract F19628-86-C-0056)  
(AD-A203694; SSS-R-88-9339; W/O-11304; AFGL-TR-88-0057)  
Avail: NTIS HC A03/MF A01 CSCL 22/1

The importance has been discussed of accurately including the omission of secondary and backscattered electrons in the calculations of flux balances that are used to predict the equilibrium potential of satellites during intense electron precipitation. This concept is applied to a sequence of electron and ion flux spectra observed by DMSP satellites to determine the levels of negative charging, if any, experienced by the satellites. The net electron current incident minus backscattered and secondary electrons is a diagnostic quantity that can be used to determine whether charging has occurred. Using simple models of the satellite and ion collection, along with secondary and backscatter yields for the appropriate covering, one can quickly scan large amounts of data for charging events and estimate the equilibrium potential. GRA

AB9-21022# Air Force Geophysics Lab., Hanscom AFB, MA.  
PRECIPITATING ION AND ELECTRON DETECTORS (SSJ/4) FOR THE BLOCK 50/FLIGHT 8 DMSP (DEFENSE METEOROLOGICAL SATELLITE PROGRAM) SATELLITE Interim Report

T. L. SCHUMAKER, D. A. HARDY, S. MORAN, A. HUBER, J. MCGARITY, and J. PANTAZIS 4 Feb. 1988 61 p  
(AD-A203999; AFGL-TR-88-0030; AFGL-IP-335) Avail: NTIS HC A04/MF A01 CSCL 04/1

The satellites of the Defense Meteorological Satellite Program are flown operationally to provide data for the specification of terrestrial weather and near-Earth space environment. In support of space environment specifications, the satellites, starting with Flight 6 (F6), carry an improved set of electrostatic analyzers (SSJ/4). These instruments are designed to measure the flux of precipitating electrons and ions with energies between 30 eV and 30 KeV. The data from these analyzers are routinely processed at the Air Force Geophysics Laboratory (AFGL) and are available to the scientific community. A description of the SSJ/4 electrostatic analyzers for the DMSP satellite, results of the extensive calibration of the instruments, and examples of data use are given in this report. The report was prepared to facilitate the widespread use of the SSJ/4 data. Both by itself, and in combination with other sensors on the satellite, the SSJ/4 detectors provide important data for the study of auroral processes. GRA

AB9-21090# Saarland Univ., Saarbrücken (Germany, F.R.). Inst. fuer Werkstoffphysik.

MARTENSITIC PHASE TRANSITIONS IN NANOCRYSTALLINE MATERIALS Interim Report No. 4, 2 Dec. 1987 - 2 Jun. 1989

H. GLEITER 2 Jun. 1988 3 p  
(Contract DAJ445-87-C-0008)  
(AD-A203636; R/D-5647-MS-01.4) Avail: NTIS HC A01/MF A01 CSCL 07/2

As indicated in our third interim report, we have carried out Mossbauer spectroscopy on isolated nanometer-sized crystals cooled to 4.2 K under ultra-high vacuum conditions in order to



decide whether or not nucleation of martensite is possible in nanometer-sized, unconstrained crystals. The spectrometer necessary to carry out those experiments was developed in January 1988. It consists of a quartz tube which has locally a section of two thin walls which are transparent to the Mossbauer gamma-rays. The loose powder of isolated small crystals is filled under UHV conditions into the tube and is subsequently cooled to 4.2 K. However, when we recorded the Mossbauer spectra, they turned out not to be conclusive for two reasons: (1) The isolated 5 nm Fe-Ni crystals are superparamagnetic at 4.2 K. (2) The resolution of the spectra is not as high as required to distinguish between bcc and fcc FeNi due to the small amount of material in the tube. GRA

**N89-24705\*** National Aeronautics and Space Administration, Washington, DC.

#### TECHNOLOGY REQUIREMENTS FOR ADVANCED NASA MISSIONS

HENRY B. CURTIS In NASA, Lewis Research Center, Space Photovoltaic Research and Technology, 1988. High Efficiency, Space Environment, and Array Technology p 3-9 Apr. 1988  
 Avail: NTIS HC A15/MF A03 CSCL 22/1

Two recent reports, one by the National Commission on Space and the second by the Ride committee, have urged NASA to look at a variety of future missions. Among these are manned missions to Mars and permanent bases on the moon and Mars. Addressed here is a wide variety of technologies needed for such missions as well as areas where power is required. An estimate of power ranges and photovoltaic opportunities is also presented. Author

**N89-25296\*** National Aeronautics and Space Administration, Ames Research Center, Moffett Field, CA.

#### SPACE STATION ARCHITECTURE, MODULE, BERTHING HUB, SHELL ASSEMBLY, BERTHING MECHANISM AND UTILITY CONNECTION CHANNEL Patent

MARC M. COHEN, inventor (to NASA) 28 Feb. 1989 15 p  
 (NASA-CASE-ARC-11505-2; US-PATENT-4,807,834;  
 US-PATENT-APPL-SN-159072; US-PATENT-CLASS-244-159;  
 US-PATENT-CLASS-244-161; US-PATENT-CLASS-285-302)  
 Avail: US Patent and Trademark Office CSCL 22/2

A Space Station includes a plurality of modules, and berthing hubs, joined by interconnections which are sideways connectable. The modules and hubs are fastened together in a triangular configuration in three dimensions. The interconnections include a pair of opposed, axially aligned, flanged ports, and a clamp latch formed from a plurality of sections hinged along their length and extending circumferentially around the flanged ports. A utilities connection channel extends between ports. The channel has a shell with utilities connectors movable between an extended position to mating connectors in the modules and a withdrawn position. Assembly sequence and common module shell structure is detailed.

Official Gazette of the U.S. Patent and Trademark Office

**N89-28037\*** National Aeronautics and Space Administration, Washington, DC.

#### TECHNOLOGY FOR LARGE SPACE SYSTEMS: A BIBLIOGRAPHY WITH INDEXES (SUPPLEMENT 20)

Jun. 1989 183 p  
 (NASA-SP-7046(20); NAS 1.21:7046(20)) Avail: NTIS HC A09 CSCL 22/2

This bibliography lists 694 reports, articles, and other documents introduced into the NASA Scientific and Technical Information System between July, 1988 and December, 1988. Its purpose is to provide helpful information to the researcher or manager engaged in the development of technologies related to large space systems. Subject areas include mission and program definition, design techniques, structural and thermal analysis, structural dynamics and control systems, electronics, advanced materials, assembly concepts, and propulsion. Author

**N89-28547\*** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

#### A TORSIONAL SUSPENSION SYSTEM FOR TESTING SPACE STRUCTURES Patent Application

WILMER H. REED, III, inventor (to NASA) and RONALD R. GOLD, inventor (to NASA) (Dynamic Engineering, Inc., Newport News, VA) 26 May 1989 12 p  
 (NASA-CASE-LAR-14149-1-SB; NAS 1.71:LAR-14149-1-SB;  
 US-PATENT-APPL-SN-357757) Avail: NTIS HC A03/MF A01 CSCL 14/2

A low frequency torsional suspension system for testing a space structure uses a plurality of suspension stations attached to the space structure along the length thereof in order to suspend the space structure from an overhead support. Each suspension station includes a disk pivotally mounted to the overhead support, and two cables which have upper ends connected to the disk and lower ends connected to the space structure. The two cables define a parallelogram with the center of gravity of the space structure being vertically beneath the pivot axis of the disk. The vertical distance between the points of attachment of the cables to the disk and the pivot axis of the disk is adjusted to lower the frequency of the suspension system to a level which does not interfere with frequency levels of the space structure, thereby enabling accurate measurement. NASA

**N89-28552\*** National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, TX.

#### DOCKING MECHANISM FOR SPACECRAFT Patent Application

GREGORY A. LANGE, inventor (to NASA), JOHN P. MCNAMANEN, inventor (to NASA), and JOHN A. SCHLESING, inventor (to NASA) 30 Dec. 1988 24 p  
 (NASA-CASE-MSC-21386-1; NAS 1.71:MSC-21386-1;  
 US-PATENT-APPL-SN-292123) Avail: NTIS HC A03/MF A01 CSCL 22/2

A system is presented for docking a space vehicle to a space station where a connecting tunnel for in-flight transfer of personnel is required. Cooperable coupling mechanisms include docking rings on the space vehicle and space station. The space station is provided with a tunnel structure, a retraction mechanism, and a docking ring. The vehicle coupling mechanism is designed to capture the station coupling mechanism, arrest relative spacecraft motions while limiting loads to acceptable levels, and then realign the spacecraft for final docking and tunnel interconnection. The docking ring of the space vehicle coupling mechanism is supported by linear attenuator actuator devices, each of which is controlled by a control system which receives loading information signals and attenuator stroke information signals from each device and supplies output signals for controlling its linear actuation to attenuate impact loading or to realign the spacecraft for final docking and tunnel interconnection. The retraction mechanism is used to draw the spacecraft together after initial contact and coupling. Tunnel trunnions, cooperative with the latches on the space vehicle constitute the primary structural tie between the spacecraft in final docked configuration. NASA

**N89-28553\*** National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, TX.

#### SPACE MODULE ASSEMBLY APPARATUS WITH DOCKING ALIGNMENT FLEXIBILITY AND RESTRAINT Patent

WILLIE D. WHITAKER, inventor (to NASA) (McDonnell-Douglas Corp., Long Beach, CA) 7 Mar. 1989 9 p Filed 8 Oct. 1987  
 (NASA-CASE-MSC-21211-1; US-PATENT-4,809,938;  
 US-PATENT-APPL-SN-105841; US-PATENT-CLASS-244-161;  
 US-PATENT-CLASS-244-159; US-PATENT-CLASS-403-51;  
 US-PATENT-CLASS-285-226) Avail: U.S. Patent and Trademark Office CSCL 22/2

A berthing mechanism especially for use in berthing and compliant air-tight securing between manned space vehicle and modules is disclosed. The interface is provided by a pair of annular rings, one of which is typically, mechanically attached to the vehicle and the other to the module to which it is to be docked and secured. One of the two rings is attached to a base by resilient bellows. The facing surface of one annular ring is joined to a

base by a cable laced through alternating pulleys attached circumferentially so that the interface surface of that ring may be tilted to accommodate angular misalignment as the annular rings are brought into docking (berthing) contact. Interleaving guide flanges with chamfered sides provide at least some rotational misalignment correction. A plurality of electromechanical actuator/attenuator units provide means for extending one annular ring toward the other in the final stages of docking, for absorbing the initial docking shock and for drawing the annular rings into tight interface contact. Locking hooks provide for securing the interfaces.

Official Gazette of the U.S. Patent and Trademark Office

## 02

## MODELS, ANALYTICAL DESIGN TECHNIQUES, AND ENVIRONMENTAL DATA

Includes descriptions of computerized interactive systems design and development techniques, computer codes, internal and external environmental models and data.

## ABR-361759

## COMPUTER SIMULATION OF A MAGNETIC SHIELD IN A REALISTIC SPACE ENVIRONMENT

H. KROGER and P. LABELLE (Universite Laval, Quebec, Canada) ESA Journal (ISSN 0379-2285), vol. 12, no. 4, 1988, p. 491-497.

Copyright

A computer program has been developed to simulate magnetic shielding of an orbiting space station. The magnetic shield is produced by an electric current flowing through a circular loop and is taken into account in the dipole approximation. The protection offered by the shield has been studied for two different realistic space environments. A detailed local distribution and the overall flux of charged particles striking the surface of the space station have been computed as a function of the strength of the shielding magnetic field. It is shown that the electric current needed to offer satisfactory protection is feasible. Author

## ABR-36209

## COMPUTER SIMULATION PROGRAM FOR FLEXIBLE SPACE STRUCTURES

YOSHIKAZU KODAMA, HIDETOSHI KITABATAKE, and MASAHITO KURIHARA (Fujitsu, Ltd., Tokyo, Japan) In: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings, Volume 1, Tokyo, AGNE Publishing, Inc., 1988, p. 1337-1342. refs

Copyright

Effects of structural flexibilities are important for the analyses and understanding on dynamic behavior of Large Space Structures (LSS) in space. A computer simulation program is developed focusing mainly on attitude control system analyses of three-axis stabilized satellites. Dynamic simulation methods for LSS and its algorithms based on an idea of hinge-connected multibody modelings are studied. A simulation of LSS dynamics is performed, and the resultant data are arranged to visualize the LSS motions by animation film. Author

## ABR-366379

## THE SIMULATION OF MULTIBODY SYSTEMS - METHOD, TECHNOLOGICAL STATUS, AND REQUIREMENTS FOR ORBITAL SYSTEM DYNAMICS (SIMULATION VON MEHRKÖRPERSYSTEMEN - METHODE, STAND DER TECHNIK UND ANFORDERUNGEN FÜR ORBITALE SYSTEMDYNAMIK)

K. EBERT (Messerschmitt-Boelkow-Blohm GmbH, Ottobrunn, Federal Republic of Germany), S. GRAUL (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany), and R. SCHWERTASSEK (DFVLR, Oberpfaffenhofen, Federal

Republic of Germany) DGLR, Jahrestagung, Darmstadt, Federal Republic of Germany, Sept. 20-23, 1988, Paper. 10 p. In German. refs

(MBB-UK-0014-88-PUB)

The fundamental principles of multibody-system (MBS) dynamical analysis are reviewed, with a focus on their computer implementation and application to space structures. Consideration is given to the governing equations of MBS dynamics, the treatment of MBSs with rigid and elastic bodies, MBSs with control, and numerical solution schemes for the MBS equations. The use of MBS computer codes in the design of components for Columbus is considered, with particular attention to the problems of launch vehicles, orbital systems, and operational platforms; control problems of complex space structures (involving reconfiguration, large-scale movement, and manipulator systems); and simulation software. T.K.

## ABR-40463

## DYNAMIC MODELING, CONTROL THEORY AND STABILIZATION FOR FLEXIBLE STRUCTURES - INDUSTRIAL APPLICATIONS AT AEROSPATIALE, CANNES

L. PASSERON, C. TRUCHI (Aerospatiale, Division Systemes Strategiques et Spatiaux, Cannes-la-Mouille, France), and J. P. ZOLESIO (Montpellier II, Universite, France) In: Stabilization of flexible structures; Proceedings of the ComCon Workshop, Montpellier, France, Dec. 11-15, 1987, Los Angeles, CA, Optimization Software, Inc., 1988, p. 184-216. refs

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The activities of the Cannes section of Aerospatiale are reviewed. Dynamic modeling of interconnected flexible structures and the development of advanced control tools in classical control theory are addressed. Some of the industrial programs to which those tools have been applied are discussed, and an application of Hamiltonian theory to stability of a flexible spinning spacecraft is described. The most recent work carried out on adaptive optics is reviewed. C.D.

## ABR-43132

## MODELING SPACECRAFT ATTITUDE DYNAMICS ON A PERSONAL COMPUTER

JOHN W. HUNT, JR. (Johns Hopkins University, Laurel, MD) In: 1988 Annual Summer Computer Simulation Conference, 20th, Seattle, WA, July 25-28, 1988, Proceedings, San Diego, CA, Society for Computer Simulation International, 1988, p. 227-230. refs

Copyright

A computer simulation of a gravity-gradient stabilized spacecraft is described. The governing equations of motion are described along with a variety of torque models. Attention is also given to the simulation, which was originally developed on a mainframe computer in a programming language and was transferred to PCs. Execution speeds are compared for a mainframe computer and a variety of personal computers. K.K.

ABR-43450\* National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

INTERDISCIPLINARY AND MULTILEVEL OPTIMUM DESIGN JAROSLAW SOBIESZCZANSKI-SOBIESKI (NASA, Langley Research Center, Hampton, VA) and RAPHAEL T. HAFTKA (Virginia Polytechnic Institute and State University, Blacksburg) In: Computer aided optimal design: Structural and mechanical systems. Berlin, Springer-Verlag (NATO ASI Series, Volume F27), 1987, p. 655-701. Previously announced in STAR as N87-15205. refs

Copyright

Interactions among engineering disciplines and subsystems in engineering system design are surveyed and specific instances of such interactions are described. Examination of the interactions that a traditional design process in which the numerical values of major design variables are decided consecutively is likely to lead to a suboptimal design. Supporting numerical examples are a glider and a space antenna. Under an alternative approach introduced, the design and its sensitivity data from the subsystems and disciplines are generated concurrently and then made available to

the system designer enabling him to modify the system design so as to improve its performance. Examples of a framework structure and an airliner wing illustrate that approach. Author

**A89-45779**

**ANIMATION/SIMULATION FOR CONSTRUCTION PLANNING**

DAVID C. ATKINS (Bechtel Western Power Co., Newark, CA) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 670-678. Copyright

A software system for efficient scheduling of space construction has been developed. The system animates the proposed construction sequence, simulating a time lapse film of activities as they would be performed in the field. An overview is given of the construction computer-aided engineering system which is the central component of the overall software system. The functions and features of the simulator and its user interface are outlined and the simulator outputs are described, including the installation script file and animated videotape. Current applications of the method to space construction are considered. C.D.

**A89-45821**

**SPACE FACILITIES IN CLASSROOM 'IMAGINEERING'**

JAMES A. WISE (Grand Valley State University, Grand Rapids, MI) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 1153-1162. Copyright

Results are presented from two space facility design products produced by architecture students. The first project is a design for the 'Space Architecture' section of an educational exhibition. The second project is an interior design for the Space Station Habitation Module. The features of the Habitation Module design include the enhancement of internal volume using walls that 'pop out' into the main circulation space, removable common walls between cabins to accommodate married couples, and the placement of the wardroom in the end cap at a 90 degree angle with respect to the remainder of the module. R.B.

**A89-45822**

**SPACE CONSTRUCTION ANIMATOR - FUNCTIONAL REQUIREMENTS**

WALTER E. RODRIGUEZ-RAMOS and BARNEY JONES (Georgia Institute of Technology, Atlanta) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 1163-1174. refs

Copyright  
The development of computer graphics integrated tools for space construction operations is discussed. Issues important for determining the requirements for space construction animation systems are examined. The possible applications of computer animation technology in space construction are outlined. Recommendations are made for evaluating current research on the use of animation systems in space construction, developing future projects related to space computer technologies, and determining the animation requirements for space-related activities. R.B.

**A89-46141**

**ALGORITHMS AND COMPUTATIONAL TECHNIQUES IN STOCHASTIC OPTIMAL CONTROL**

HAGOP V. PANOSSIAN (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: Control and dynamic systems. Volume 28. Part 1. San Diego, CA, Academic Press, Inc., 1988, p. 1-55. refs

Copyright

The paper discusses research and theories pertaining to the optimal control of stochastic systems with multiplicative and additive noise that are represented by linear/bilinear models. The algorithms and numerical techniques that are utilized in solving these problems

are surveyed. It is believed that the advent of supersonic aircraft with very high performance requirements and of structures such as the Space Station promise some realistic ground for modeling and control design with multiplicative and additive noise of complex control systems. K.K.

**A89-48155\*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

**PLAID AS A MAINTAINABILITY TOOL**

BARBARA J. WOOLFORD, LINCA S. ORR, and FRANCES E. MOUNT (NASA, Johnson Space Center, Houston, TX) AIAA and NASA, Symposium on the Maintainability of Aerospace Systems, Anaheim, CA, July 26, 27, 1988. 11 p. (AIAA PAPER 88-5044) Copyright

PLAID is a computer-aided design tool for human factors engineering which has been used successfully in the Space Shuttle program and for design analysis of Space Station Freedom. PLAID capability includes analysis of visual fields of view, of the ability to reach a specified point, and of spatial conflicts. It enables the creation of animations which depict whole sequences of motions of astronauts and equipment. The PLAID graphics capability is described and its application to man-systems integration is briefly examined. The use of PLAID for maintainability is addressed, and future plans for PLAID are discussed. C.D.

**A89-54676**

**AEROSPACE TESTING SEMINAR, 11TH, MANHATTAN BEACH, CA, OCT. 11-13, 1988, PROCEEDINGS**

Seminar sponsored by the Institute of Environmental Sciences and Aerospace Corp. Mount Prospect, IL, Institute of Environmental Sciences, 1988, 293 p. For individual items see A89-54677 to A89-54699.

The conference presents papers on space vehicle flight performance and test effectiveness, aerospace test techniques, national and international test facilities, new mission test requirements, and Space Station testing issues. Attention is given to Space Shuttle solid rocket motor testing for return to flight, integrated ASAT missile verification testing, upgraded environmental testing of Titan T34D components, and system level acoustic testing. Other topics include knowledge-based systems for data acquisition/reduction, the use of model parameters in the prediction of buckling of externally pressurized shells, thermal vacuum testing impacts related to high-temperature power systems, terrestrial satellite storage, and vibration testing of flexible duct assemblies. K.K.

**N89-21014** Virginia Polytechnic Inst. and State Univ., Blacksburg.

**TIME OPTIMAL BLEWING OF FLEXIBLE SPACECRAFT Ph.D. Thesis**

JOSEPH ZALMAN BEN-ASHER 1988 148 p  
Avail: Univ. Microfilms Order No. DA8824964

The time optimal slewing problem for flexible spacecraft is considered. We study single-axis rotational maneuvers for a simple flexible system, consisting of a rigid hub with an elastic appendage. The equations of motions are derived by Hamilton's Principle, and a discrete nonlinear model is obtained by the assumed modes method. The problem is first solved in a discrete linearized space by parameter optimization. Optimality is verified by Pontryagin's Maximum Principle. The linear solutions are then used to obtain the time optimal solutions for the nonlinear problem by a multiple-shooting algorithm. Although this approach is applicable to arbitrary boundary conditions, this work is confined, almost exclusively, to rest-to-rest maneuvers. These maneuvers are shown to possess some interesting symmetric and asymptotic properties. The problem is further analyzed in infinite-dimensional space, and the convergence of the finite-dimensional approximations is studied. Finally, a soft version of the time optimal slewing problem is considered, where the control is bounded only by a penalty term in the cost functional. A perturbation technique is applied to further simplify this problem. Dissert. Abstr.



**N89-23501\*** National Inst. of Standards and Technology, Gaithersburg, MD. Center for Fire Research.

**EXPERT SYSTEMS APPLIED TO SPACECRAFT FIRE SAFETY**  
Final Report

RICHARD L. SMITH and TAKASHI KASHIWAGI Jun. 1989  
13 p

(Contract NASA ORDER C-32000-M)  
(NASA-CR-182256; E-4812; NAS 1.26:182256) Avail: NTIS HC  
A53/MF A01 CSCL 22/2

Expert systems are problem-solving programs that combine a knowledge base and a reasoning mechanism to simulate a human expert. The development of an expert system to manage fire safety in spacecraft, in particular the NASA Space Station Freedom, is difficult but clearly advantageous in the long-term. Some needs in low-gravity flammability characteristics, ventilating-flow effects, fire detection, fire extinguishment, and decision models, all necessary to establish the knowledge base for an expert system, are discussed. Author

**N89-24666\*** Lockheed Missiles and Space Co., Palo Alto, CA.  
**COMPUTATIONAL ASPECTS OF MULTIBODY DYNAMICS**

K. C. PARK In NASA, Langley Research Center, Computational Methods for Structural Mechanics and Dynamics p 527-536 May 1989

Avail: NTIS HC A12/MF A02 CSCL 20/11

Computational aspects are addressed which impact the requirements for developing a next generation software system for flexible multibody dynamics simulation which include: criteria for selecting candidate formulation, pairing of formulations with appropriate solution procedures, need for concurrent algorithms to utilize computer hardware advances, and provisions for allowing open-ended yet modular analysis modules. Author

**N89-25180\*** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

**DEMONSTRATION OF DECOMPOSITION AND OPTIMIZATION IN THE DESIGN OF EXPERIMENTAL SPACE SYSTEMS**

SHARON PADULA, CHRIS A. SANDRIDGE, RAPHAEL T. HAFTKA (Virginia Polytechnic Inst. and State Univ., Blacksburg.), and JOANNE L. WALSH In its Recent Advances in Multidisciplinary Analysis and Optimization, Part 1 p 297-316 Apr. 1989

Avail: NTIS HC A23/MF A03 CSCL 22/2

Effective design strategies for a class of systems which may be termed Experimental Space Systems (ESS) are needed. These systems, which include large space antenna and observatories, space platforms, earth satellites and deep space explorers, have special characteristics which make them particularly difficult to design. It is argued here that these same characteristics encourage the use of advanced computer-aided optimization and planning techniques. The broad goal of this research is to develop optimization strategies for the design of ESS. These strategies would account for the possibly conflicting requirements of mission life, safety, scientific payoffs, initial system cost, launch limitations and maintenance costs. The strategies must also preserve the coupling between disciplines or between subsystems. Here, the specific purpose is to describe a computer-aided planning and scheduling technique. This technique provides the designer with a way to map the flow of data between multidisciplinary analyses. The technique is important because it enables the designer to decompose the system design problem into a number of smaller subproblems. The planning and scheduling technique is demonstrated by its application to a specific preliminary design problem. Author

**N89-25289\*** Technische Univ., Berlin (Germany, F.R.). Inst. of Aerospace.

**FLIGHT PERFORMANCE MODEL FOR A GEOSTATIONARY TRANSPORTATION SYSTEM**

M. NIELKE 1 Aug. 1988 42 p  
(LR-MITT-206; ETN-89-04581) Avail: NTIS HC A53/MF A01

A flight performance model for a geostationary transportation system is described. The model specifies all requirements concerning orbit and attitude control as well as rendezvous and

docking. Several transportation missions are considered and analyzed to determine most suitable transfer trajectories and attitude control strategies for minimizing velocity requirements. Transfer distances of 5 to 130,000 km lead to flight durations of 0.5 to 70 hr and a velocity requirement of 10 to 1600 m/sec.

ESA

**N89-25522\*** National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, TX.

**A SPACE SYSTEMS PERSPECTIVE OF GRAPHICS SIMULATION INTEGRATION**

R. BROWN, C. GOTT, G. SABONSKI, and D. BOCHSLER (LinCom Corp., Houston, TX.) In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 2 p 267-272 1 Jul. 1987

Avail: NTIS HC A18/MF A03 CSCL 09/2

Creation of an interactive display environment can expose issues in system design and operation not apparent from nongraphics development approaches. Large amounts of information can be presented in a short period of time. Processes can be simulated and observed before committing resources. In addition, changes in the economics of computing have enabled broader graphics usage beyond traditional engineering and design into integrated telerobotics and Artificial Intelligence (AI) applications. The highly integrated nature of space operations often tend to rely upon visually intensive man-machine communication to ensure success. Graphics simulation activities at the Mission Planning and Analysis Division (MPAD) of NASA's Johnson Space Center are focusing on the evaluation of a wide variety of graphical analysis within the context of present and future space operations. Several telerobotics and AI applications studies utilizing graphical simulation are described. The presentation includes portions of videotape illustrating technology developments involving: (1) coordinated manned maneuvering unit and remote manipulator system operations, (2) a helmet mounted display system, and (3) an automated rendezvous application utilizing expert system and voice input/output technology. Author

**N89-26583\*** Mils Corp., McLean, VA.  
**A SITUATED REASONING ARCHITECTURE FOR SPACE-BASED REPAIR AND REPLACE TASKS**

BEN BLOOM, DEBRA MOGRATH, and JIM SANBOFF In NASA, Goddard Space Flight Center, The 1989 Goddard Conference on Space Applications of Artificial Intelligence p 49-59 Apr. 1989

Avail: NTIS HC A17/MF A03 CSCL 09/2

Space-based robots need low level control for collision detection and avoidance, short-term load management, fine-grained motion, and other physical tasks. In addition, higher level control is required to focus strategic decision making as missions are assigned and carried out. Reasoning and control must be responsive to ongoing changes in the environment. Research aimed at bridging the gap between high level artificial intelligence (AI) planning techniques and task-level robot programming for telerobotic systems is described. Situated reasoning is incorporated into AI and Robotics systems in order to coordinate a robot's activity within its environment. An integrated system under development in a component maintenance domain is described. It is geared towards replacing worn and/or failed Orbital Replacement Units (ORUs) designed for use aboard NASA's Space Station Freedom based on the collection of components available at a given time. High level control reasons in component space in order to maximize the number operational component-calls over time, while the task-level controls sensors and effectors, detects collisions, and carries out pick and place tasks in physical space. Situated reasoning is used throughout the system to cope with component failures, imperfect information, and unexpected events. Author

**N89-26589\*** Ford Aerospace and Communications Corp., Seabrook, MD. Space Systems Engineering Operation.

**A HEURISTIC APPROACH TO INCREMENTAL AND REACTIVE SCHEDULING**

JUDE B. COUBRY and DAVID R. ZOCH In NASA, Goddard

Space Flight Center, The 1989 Goddard Conference on Space Applications of Artificial Intelligence p 127-140 Apr. 1989  
 Avail: NTIS HC A17/MF A03 CSCL 05/1

An heuristic approach to incremental and reactive scheduling is described. Incremental scheduling is the process of modifying an existing schedule if the initial schedule does not meet its stated initial goals. Reactive scheduling occurs in near real-time in response to changes in available resources or the occurrence of targets of opportunity. Only minor changes are made during both incremental and reactive scheduling because a goal of re-scheduling procedures is to minimally impact the schedule. The described heuristic search techniques, which are employed by the Request Oriented Scheduling Engine (ROSE), a prototype generic scheduler, efficiently approximate the cost of reaching a goal from a given state and effective mechanisms for controlling search.

Author

**N89-26604\*** Maryland Univ., College Park. Dept. of Computer Science.

#### A CONNECTIONIST MODEL FOR DYNAMIC CONTROL

KEVIN C. WHITFIELD, SHARON M. GOODALL, and JAMES A. REGGIA In NASA, Goddard Space Flight Center, The 1989 Goddard Conference on Space Applications of Artificial Intelligence p 357-370 Apr. 1989

(Contract NAG1-885; NSF IRI-84-51430)  
 Avail: NTIS HC A17/MF A03 CSCL 09/2

The application of a connectionist modeling method known as competition-based spreading activation to a camera tracking task is described. The potential is explored for automation of control and planning applications using connectionist technology. The emphasis is on applications suitable for use in the NASA Space Station and in related space activities. The results are quite general and could be applicable to control systems in general.

Author

**N89-26623\*** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

#### INTEGRATED STRUCTURE/CONTROL LAW DESIGN BY MULTILEVEL OPTIMIZATION

MICHAEL G. GILBERT and DAVID K. SCHMIDT Jun. 1989 12 p Presented at the AIAA Guidance, Navigation and Control Conference, Boston, MA, 14-16 Aug. 1989  
 (NASA-TM-101622; NAS 1.15:101622) Avail: NTIS HC A03/MF A01 CSCL 09/2

A new approach to integrated structure/control law design based on multilevel optimization is presented. This new approach is applicable to aircraft and spacecraft and allows for the independent design of the structure and control law. Integration of the designs is achieved through use of an upper level coordination problem formulation within the multilevel optimization framework. The method requires the use of structure and control law design sensitivity information. A general multilevel structure/control law design problem formulation is given, and the use of Linear Quadratic Gaussian (LQG) control law design and design sensitivity methods within the formulation is illustrated. Results of three simple integrated structure/control law design examples are presented. These results show the capability of structure and control law design tradeoffs to improve controlled system performance within the multilevel approach.

Author

**N89-27404\*** Virginia Polytechnic Inst. and State Univ., Blacksburg. Interdisciplinary Center for Applied Mathematics.

#### MODELING AND COMPUTATIONAL ALGORITHMS FOR PARAMETER ESTIMATION AND OPTIMAL CONTROL OF AEROELASTIC SYSTEMS AND LARGE FLEXIBLE STRUCTURES Final Report, 30 Sep. 1985 - 30 Sep. 1988

JOHN A. BURNS and EUGENE M. CLIFF 15 Feb. 1989 14 p (Contract AF-AFOSR-8287-85; AF PROJ. 2204)  
 (AD-A208274; AFOSR-89-0600TR) Avail: NTIS HC A03/MF A01 CSCL 20/4

The basic goal of this project is the study of computational algorithms for control design of partial functional differential equations that model structural and fluid dynamic systems. We investigated several aspects of the development of computational

algorithms for identification and control of distributed parameter systems. We also spent considerable effort on specific applications involving elastic, aeroelastic and viscoelastic systems. Progress was made on many of these problems. However, in this report we shall concentrate on the major accomplishments.

GRA

**N89-28775\*** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

#### CSM PARALLEL STRUCTURAL METHODS RESEARCH

OLAF O. STORAASLI In its NASA Workshop on Computational Structural Mechanics 1987, Part 1 p 25-59 Feb. 1989  
 Avail: NTIS HC A17/MF A03 CSCL 20/11

Parallel structural methods, research team activities, advanced architecture computers for parallel computational structural mechanics (CSM) research, the FLEX/32 multicomputer, a parallel structural analysis testbed, blade-stiffened aluminum panel with a circular cutout and the dynamic characteristics of a 60 meter, 54-bay, 3-longeron deployable truss beam are among the topics discussed.

Author

**N89-29709\*** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

#### NASA WORKSHOP ON COMPUTATIONAL STRUCTURAL MECHANICS 1987, PART 3

NANCY P. SYKES, ed. (Analytical Services and Materials, Inc., Hampton, VA.) Feb. 1989 419 p Workshop held in Hampton, VA, 18-20 Nov. 1987; sponsored by NASA, Langley Research Center, Hampton, VA, and NASA, Lewis Research Center, Cleveland, OH  
 (NASA-CP-10012-PT-3; NAS 1.55:10012-PT-3) Avail: NTIS HC A18/MF A03 CSCL 20/11

Computational Structural Mechanics (CSM) topics are explored. Algorithms and software for nonlinear structural dynamics, concurrent algorithms for transient finite element analysis, computational methods and software systems for dynamics and control of large space structures, and the use of multi-grid for structural analysis are discussed.

**N89-29806\*** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

#### LARC COMPUTATIONAL DYNAMICS OVERVIEW

J. M. HUSNER In its NASA Workshop on Computational Structural Mechanics 1987, Part 3 p 1013-1041 Feb. 1989  
 Avail: NTIS HC A18/MF A03 CSCL 20/11

Present research centers on the development of advanced computational methods for transient simulation analyses. Aircraft, launch vehicles and space structure components are potential applications, but primary focus is presently on large space structures. There are both in-house and out-of-house activities. The in-house activity centers around the development of a multibody simulation tool for truss-like structures called LATDYN for Large Angle Transient DYNAMics. Multibody analysis involves articulation of structural components as well as robotic maneuvers. These items are necessary for construction (erection or deployment) of large space structures in orbit and the carrying out of certain operations on board the space station. Thus, part of the in-house activity involves the development of methods which treat the changing mass, stiffness and constraints associated with articulating systems. The out-of-house activity involves subcycling, development of large deformation/motion beam formulation, constraint stabilization and direct time integration transient algorithms in parallel computing.

Author

**N89-29809\*** Colorado Univ., Boulder. Coll. of Engineering and Applied Science.

#### COMPUTATIONAL METHODS AND SOFTWARE SYSTEMS FOR DYNAMICS AND CONTROL OF LARGE SPACE STRUCTURES

K. C. PARK, C. A. FELIPPA, CHARBEL FARHAT, J. D. DOWNER, J. G. CHIOU, and W. K. BELVIN In NASA, Langley Research Center, NASA Workshop on Computational Structural Mechanics 1987, Part 3 p 1105-1132 Feb. 1989  
 Avail: NTIS HC A18/MF A03 CSCL 20/11

### 03 STRUCTURAL CONCEPTS

The deployment, assembly and mission-oriented maneuvering of space structures in orbit will trigger large motions of flexible, truss-type structures. In addition, the presence of on-board controls both for attitude stabilization and specified vibration tolerance requirements may further complicate the dynamic behavior of the orbiting structures. Because of safety and cost considerations, the dynamic response of the combined structural and control systems must be predicted reliably. This need can only be met through the development of reliable and efficient simulation capabilities, since there is general agreement that on-orbit experiments should be limited because of cost, time and facility constraints. The long-term objective of this research effort is to develop a next-generation computer simulator for the dynamics and control of large space structures. The simulator will be based on integrating four research thrusts: a new multibody dynamics formulation methodology, modeling capabilities in long/slender truss-beam component; with realistic joints, efficient computational procedures that can be implemented either in sequential or concurrent computers, and prototype simulation modules that can be easily processed into a modern large-scale engineering software system such as the NASA/Computational Structural Mechanics (CSM) testbed. Author

### 03

#### STRUCTURAL CONCEPTS

Includes analyses and descriptions of different Space Station structural concepts, arrangements, testing, methods of construction and/or manufacturing and specific rotary joints, structural nodes, and columns.

**A89-34257**

**A NEW APPROXIMATION TO THE SYMBOL ERROR PROBABILITY FOR CODED MODULATION SCHEMES WITH MAXIMUM LIKELIHOOD SEQUENCE DETECTION**  
WILLIAM HARROLD (STC Technology, Ltd., Harlow, England) IEEE Transactions on Communications (ISSN 0090-6778), vol. 37, April 1989, p. 340-352. Research supported by Marconi Secure Radio. refs  
(Contract SERC-85305720)  
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The power efficiency of coded modulation schemes in additive white Gaussian noise depends on the signal-space distribution of their most common error events. Symbol-error-probability calculation allowing for the pairwise interaction of these error events is discussed. Two optimality criteria are considered for detectors. The first minimizes the probability of symbol-error for each symbol decision. This is called the symbol-to-symbol detector. The second (which is superior) is the maximum-likelihood sequence detector (MLSD). A lower bound for the symbol-to-symbol detector and an approximation to the MLSD symbol-error probability are described. The theoretical performance difference between these two detectors is given. The results are more accurate than minimum-squared Euclidean distance predictions, especially at low and intermediate signal-to-noise ratios. The MLSD symbol-error probability approximation is obtained for considerably less cost than computer simulation and gives more insight into the signal-space structure of the scheme being analyzed. Numerical results are presented for a continuous phase modulation (CPM) example. I.E.

**A89-34358\*** Houston Univ., TX.

#### IDENTIFICATION OF LARGE SPACE STRUCTURES - OVERVIEW

EUGENE DENMAN (Houston, University, TX), JER-NAN JUANG (NASA, Langley Research Center, Hampton, VA), JOHN JUNKINS (Texas A & M University, College Station), MANOHAR KAMAT (Georgia Institute of Technology, Atlanta), T. K. HASSELMAN et

al. Journal of Aerospace Engineering (ISSN 0893-1321), vol. 1, April 1988, p. 88-104. Research supported by USAF. refs  
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The system identification process presently discussed for the case of large space structures uses the observed input to a system and its observed response, or output, to derive an analytical model of the system which can then be used to predict its response to future inputs. Due to their size and complexity, as well as the intrinsic difficulty of identifying the environment in which they function, large space structures will require vast amounts of information, encompassing both experimental and analytical data for identification. A status evaluation is made of the structural system identification literature to date. O.C.

**A89-34364**

**THERMAL EFFECTS ON VERY LARGE SPACE STRUCTURES**  
RAMESH B. MALLA (Connecticut, University, Storrs), WILLIAM A. NASH, and THOMAS J. LARDNER (Massachusetts, University, Amherst) Journal of Aerospace Engineering (ISSN 0893-1321), vol. 1, July 1988, p. 171-190. refs  
(Contract AF-AFOSR-83-0025)  
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The present study of direct solar, earth-albedo, and direct earth radiation-induced thermal effects on the orbital and attitude motions and axial deformation of a very large, axially flexible space structure as it figures a planar-pitch motion gives attention to the influences of the area/mass ratio of the structure. Radiation thermal effects are found to be significant in causing structural deformation and in producing libration in the attitude angle of a large space structure, although orbital parameter effects are negligible. While the effects of the earth's albedo are appreciable in LEO, they too are negligible in GEO. The area/mass ratio is found to yield drastic changes in large space structures' thermal responses. O.C.

**A89-34368**

#### ANIMATION TOOLS FOR EXTRATERRESTRIAL CONSTRUCTION

WALTER E. RODRIGUEZ-RAMOS and BARNEY JONES (Georgia Institute of Technology, Atlanta) Journal of Aerospace Engineering (ISSN 0893-1321), vol. 1, Oct. 1988, p. 238-247. Research sponsored by NSF. refs  
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The presently proposed development of space construction-simulating 'animation tools' for the evaluation of extraterrestrial design and construction methods would integrate those engineering operations in space in light of functional requirements derived from an assessment of technology-development trends. Computer animation offers a unified approach to the modeling of the spatial dynamics that are crucial to the planning and control of construction activities, as well as the evaluation of automation models. For remotely monitored processes, the timely provision of critical information in a readily understood format may greatly aid the anticipation of interference or hazard conditions. O.C.

**A89-34372**

**SPACE STATION STRUCTURE MODAL SELECTION CRITERIA**  
ALAN K. CASERIO (McDonnell Douglas Astronautics Co., Huntington Beach, CA) and ROBIN SHEPHERD (California, University, Irvine) Journal of Aerospace Engineering (ISSN 0893-1321), vol. 2, Jan. 1989, p. 20-40. Research sponsored by McDonnell Douglas Astronautics Co. refs  
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Two of the many criteria that may be used to identify the natural modes of such structural dynamic analysis problems as large space structures and establish their order of increasing importance are examined: (1) the establishment of a 'completeness index' reflecting the model identities satisfied by the natural frequencies and integrals of the mode shapes, and (2) the determination of displacements at a point of excitation and a response point. Both selection methods are implemented on a simplified model of the Initial Operating Configuration Space Station;



comparative transient-response analyses are made, and it is shown that mode selection is a function of more than one variable.

O.C.

AB9-34939

#### THE EFFECT OF NON-UNIFORM INTERFACIAL PRESSURES ON THE THERMAL CONDUCTANCE IN BOLTED AND RIVETED JOINTS

C. V. MADHUSUDANA (New South Wales, University, Kensington, Australia), G. P. PETERSON, and L. S. FLETCHER (Texas A & M University, College Station) IN: Collected papers in heat transfer 1988; Proceedings of the ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 57-67. Research supported by Texas A & M University. refs

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A literature review is presented addressing the interfacial pressure distribution and the size of the contact zone insofar as they affect the thermal contact resistance in riveted joints. A survey is also presented of the experimental work on heat transfer in bolted joints. The size of the actual contact zone is identified as an important parameter affecting both the microscopic and the macroscopic resistances. It is shown that the exact form of the stress distribution within the contact zone is immaterial in the total microscopic conductance computation if the available theoretical results for local solid spot conductance are used. If the experimental correlations are used, then the computed conductances may differ about 5-10 percent depending on the type of stress distribution chosen. It is also shown that, for a given load, the total microscopic conductance may be increased by increasing the loading radius and/or the plate thickness.

S.A.V.

AB9-35048\*# National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

#### PARAMETER IDENTIFICATION FOR VIBRATION CONTROL OF SCOLE

D. W. SPARKS, JR., R. C. MONTGOMERY, R. C. ELDER, and D. B. LENOX (NASA, Langley Research Center, Hampton, VA) IN: Recent advances in control of nonlinear and distributed parameter systems, robust control, and aerospace control applications; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 203-209. refs

Copyright

A least-squares identification method has been used to derive an empirical model of the vibrational dynamics of the Spacecraft Control Laboratory Experiment, an apparatus for testing parameter identification and control schemes for large flexible space structures. Testing is performed by exciting the structure with torque wheels. Linear least-squares analysis is employed to obtain the parameters that best fit the output of an autoregressive model to the data, and to determine the control effectiveness of the torque wheels using the excitation portion of the test data.

R.R.

AB9-35199#

#### THERMAL POSTBUCKLING BEHAVIOUR OF THIN SIMPLY SUPPORTED CIRCULAR AND SQUARE PLATES ON ELASTIC FOUNDATION

K. KANAKA RAJU and G. VENKATESWARA RAO (ISRO, Vikram Sarabhai Space Centre, Trivandrum, India) Aeronautical Society of India, Journal (ISSN 0001-9267), vol. 40, Aug. 1988, p. 211-213.

The thermal postbuckling behavior of thin circular and square plates with simply supported edges was investigated using a Rayleigh-Ritz method; this formulation considers the effect of elastic foundation on the postbuckling behavior of plates. Closed form solutions are presented for the linear critical thermal load parameter and for the nonlinear thermal load parameter in the postbuckling region. Numerical results are given for the thermal load parameter for various central deflections of the plates and for various foundation moduli. It is shown that the effect of elastic foundation

is to increase the critical thermal load parameter and to decrease the effect of nonlinearity in the postbuckling region.

I.S.

AB9-35285

#### SATURATED MODAL COST ANALYSIS APPLIED TO THE CONTROL OF A FLEXIBLE STRUCTURE

R. P. G. HEATH and B. A. WHITE (Royal Military College of Science, Cranfield, England) IN: International Conference on Control 88, Oxford, England, Apr. 13-15, 1988. Proceedings. London, Institution of Electrical Engineers, 1988, p. 559-563. refs

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Saturated Modal Cost Analysis (SMCA) is introduced for the first time. It is shown that, when a relay-type actuator possessing a brick-wall type low-pass filter action is implemented, that MCA number crunching can be significantly reduced for large flexible space structures. As the torque capabilities of gas jets are generally higher than those of reaction wheels, the latter play a negligible part in the SMCA model reduction costing technique and may thus be neglected, reducing the number crunching still further.

C.D.

AB9-35295

#### ROBUST STABILIZATION OF A FLEXIBLE SPACE PLATFORM - AN H(INFINITY) COPRIME FACTOR APPROACH

D. MCFARLANE, K. GLOVER (Cambridge University, England), and M. NOTON (British Aerospace, PLC, London, England) IN: International Conference on Control 88, Oxford, England, Apr. 13-15, 1988. Proceedings. London, Institution of Electrical Engineers, 1988, p. 677-682. refs

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A new feedback design methodology based on the normalized left coprime factorization robust stabilization using H(infinity) techniques is described. The technique is applied to the control of a hypothetical but representative flexible space platform. The technique provides stability and performance in the presence of parameter uncertainty.

C.D.

AB9-35394#

#### RELIABILITY-BASED OPTIMIZATION OF STRUCTURES

WEIJI LI (Northwestern Polytechnical University, Xian, People's Republic of China) Northwestern Polytechnical University, Journal (ISSN 1000-2758), vol. 7, April 1989, p. 147-154. In Chinese, with abstract in English. refs

A procedure for reliability-based optimization of complex structures was developed. In this procedure, major failure modes of a structure are analyzed, with the structural reliability for each major failure mode indicated by its reliability index which is a function of the design variables. Using a commonly used simplex method, it was possible to obtain the optimal structural design variables satisfying the reliability requirement. An example is presented that confirms the effectiveness of the proposed procedure.

I.S.

AB9-36039\*# Massachusetts Inst. of Tech., Cambridge.

#### ANALYSIS OF LIMIT CYCLE IN CONTROL SYSTEMS FOR JOINT-DOMINATED STRUCTURES

MATHIEU MERCADAL and WALLACE E. VANDER VELDE (MIT, Cambridge, MA) (Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987, p. 661-680) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, May-June 1989, p. 388-395. Previously cited in issue 02, p. 204, Accession no. AB9-11690. refs

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AB9-36040\*# Texas A&amp;M Univ., College Station.

#### ROBUST EIGENSTRUCTURE ASSIGNMENT BY A PROJECTION METHOD - APPLICATIONS USING MULTIPLE OPTIMIZATION CRITERIA

D. W. REW, J. L. JUNKINS (Texas A & M, College Station), and J.-N. JUANG (NASA, Langley Research Center, Hampton, VA)

### 03 STRUCTURAL CONCEPTS

Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, May-June 1989, p. 396-403. refs  
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A methodology for robust eigenstructure assignment for multivariable feedback systems is presented. The algorithm is based upon a pole placement technique using projections onto subspaces of admissible eigenvectors. New ideas are introduced to generate target (desired) sets of unitary eigenvectors and determine optimal feasible eigenvectors in a least-square sense. Useful connections are established between the pole-placement by independent modal space control and the method introduced in this paper. A multicriterion optimization algorithm is also presented, which takes efficient advantage of the present eigenstructure assignment method. These developments show significant improvement over an earlier version of this algorithm in both computational cost and accuracy. This optimization process appears to be numerically robust and suitable for high-dimensional multicriterion optimizations; it is especially attractive for computer-aided design of control systems. Author

**A89-37631#**

#### **VIBRATIONS IN AEROSPACE STRUCTURES - PREDICTION, PREVENTION AND CONTROL**

R. DAT (ONERA, Chatillon-sous-Bagneux, France) (Israel Annual Conference on Aviation and Astronautics, Tel Aviv, Israel, Feb. 2-15, 1989) ONERA, TP no. 1989-9, 1989, 13 p. refs  
(ONERA, TP NO. 1989-9)

The effects of aerospace vibrations on safety, the crew and passenger comfort, and the stability of structural elements are discussed, together with the ways by which vibrations can be reduced and controlled. Special attention is given to the problem of vibration as part of the structural design. It is shown that the structural modeling techniques differ according to the frequency range and structure size, the configuration of the structure, and the mechanism of vibration generation. It is emphasized that experiments are important not only to validate calculation codes, but also to provide data for model adjustment, to identify the characteristics of composite materials well as the characteristics of a whole structure, and to provide an evaluation of the excitation loads. I.S.

**A89-38080**

#### **TRUSS JOINT SYSTEM FOR SPACE STRUCTURES - STAR(asterisk)BAY 3**

WENDEL R. WENDEL (Star Net Structures, Inc., West Babylon, NY), TETSUJI YOSHIDA, and KENJI TAKAGI (Shimizu Construction Co., Ltd., Tokyo, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 421-430. Copyright

The major features and potential applications of Star(asterisk)Bay 3 (SB3), an advanced fastener system for large space truss structures, are reviewed and illustrated with extensive drawings and diagrams. The history of space-system fastener development is recalled; the fastener requirements of the International Space Station are examined; and the design and operation of SB3 are characterized in detail, with particular attention to the 26-collar hollow hub units, the tool-free assembly procedure, structural performance criteria, and materials and fabrication techniques. T.K.

**A89-38093**

#### **DAMPING PROPERTY OF GRAPHITE-EPOXY LAMINATES**

SHIGEO KOBAYASHI (Tokyo Metropolitan Institute of Technology, Hino, Japan), KAZUO KOYAMA (Tokyo University, Japan), and YUJI IWATA IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 515-520. refs  
Copyright

The structural damping coefficients of the graphite-epoxy laminates and the epoxy resin were measured in a vacuum chamber. The graphite-epoxy test specimens were four kinds, that

is, (0 deg)12, (90 deg)12, (0/90 deg)3S and (+45 deg/-45 deg)3S. The damping coefficients were measured for both the fundamental bending and torsional modes. The test results show that the Poisson's ratio of the epoxy resin can be approximately treated as a real value. The structural damping coefficients depend on the lamination constitution and the mode of the vibration. Theoretical values are calculated from the fundamental elastic moduli and the loss factors, which are obtained from the test results of the 0 and 90 deg laminates and from classical lamination theory. Author

**A89-38101**

#### **BENDING-TORSION COUPLED VIBRATIONS CONTROL OF LARGE SPACE STRUCTURES**

TOSHIO FUKUDA, HIDEMI HOSOKAI (Tokyo Science University, Japan), NOBUYUKI YAJIMA (Institute of Space and Astronautical Science, Sagami, Japan), and FUMIHIRO ARAI IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 565-570. refs  
Copyright

This paper presents a modeling method for bending-torsion coupled vibrations of large space structures. The bending-torsion coupled vibrations are modeled by the unconstrained-mode method. After describing the effect of the residual modes and the coupling modes in the closed-loop controlled system, a control strategy for the spillover problem of the coupled system is presented, along with stability conditions to decide control gain when the coupling is neglected. Author

**A89-38102**

#### **ACTIVE CONTROL OF A VIBRATING BEAM**

JUNJI TANI (Tohoku University, Sendai, Japan), FUMIAKI TAKAHASHI, and HIROKI UEDA IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 571-576. refs  
Copyright

The active vibration control of a cantilever beam using a piezoelectric actuator is analyzed. The problem is first reduced to a finite-degree-of-freedom system with the Galerkin method, and then the control is determined using optimal-regulator theory. The mass and the bending rigidity of the actuator are considered. Numerical calculations are carried out for a 6-DOF system and displayed for various combinations of the weighting factor, ratios of mass and bending rigidity of the actuator to those of the beam, the location of the actuator, and the structural damping coefficient. Author

**A89-38103**

#### **VIBRATION CONTROL FOR FLEXIBLE LINKED STRUCTURES**

TOSHIO FUKUDA and MASAHIRO ISOGAI (Tokyo Science University, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 577-584. refs  
Copyright

Large space structures are often subject to coupled vibrations due to disturbances. In this paper, a vibration control is proposed for such a linked flexible system by allocating actuators at the linkage joints and controlling these actuators so that the coupled vibrations should be decreased. A flexible structure with rigid bodies at each end is modeled by the bending-vibration equation; then a decoupled control is derived on the basis of this dynamics. Author

**A89-38104**

#### **EXPERIMENTAL STUDY ON VIBRATION CONTROL OF FLEXIBLE STRUCTURE**

E. SHIMEMURA, H. TAMAOKI (Waseda University, Tokyo, Japan), and S. KAWAGUCHI (Nissan Motor Co., Ltd., Tokyo, Japan) IN: International Symposium on Space Technology and Science, 16th,



Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 585-589.

Copyright

The control problem for flexible space structure is one of the key technologies for the Space Station. This paper presents an experimental approach to the control of the flexible structure using active control. An inertia-type actuator which utilizes the reaction of the moving mass is developed, and direct velocity feedback control is used as the control law. The plant for this experiment is a 2-m-high frame structure which simulates the dynamics of the flexible space structure. The experiment shows the effect of two-axis control force acting toward the actual three-dimensional structure. Author

**A89-38105**

**EXPERIMENTAL RESULTS OF LSS DAMPING ENHANCEMENT WITH ACTIVE MASS DAMPER**

TAKASHI KIDA, ISAO YAMAGUCHI, YOSHIAKI OHKAMI (National Aerospace Laboratory, Chofu, Japan), YOSHIHARU SHIMAMOTO, KEIICHI HIRAKO (Toshiba Corp, Kawasaki, Japan) et al. IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 591-596.

Copyright

This paper treats the vibration-control problem with an active mass damper, which was developed for large-space-structure (LSS) damping enhancement. The control law used is direct velocity feedback, which feeds back inertial force in proportion to the structure movement velocity. This control law, however, cannot enhance the high-mode damping because of the nonlinearities in the digital controller. In the experiment, the signal from the noncollocated sensor enhances the damping for the high modes. Author

**A89-38106**

**EXPERIMENT ON THE MISSION FUNCTION CONTROL OF SLEW MANEUVER**

HIRONORI FUJII (Tokyo Metropolitan Institute of Technology, Hino, Japan), TOSHIYUKI OHTSUKA, SATOSHI UDOU, and MASAKI TAKINAMI. IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 597-602. refs

Copyright

Results are reported concerning a control experiment on the slew maneuver of a flexible-space-structure model. The model is a rigid main body equipped with a flexible beam and is controlled to slew in a horizontal plane by a torque motor attached to the main body. The control employs a new algorithm, the mission-function control. Results of the experiment show an excellent controlled behavior of the slew maneuver. Author

**A89-38206** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**THE EQUATIONS OF MOTION FOR A GENERAL ORBITING LARGE SPACE FLEXIBLE SYSTEM**

GUANGQIAN XING (NASA/Howard University Large Space Structures Institute, Washington, DC; Beijing Institute of Control Engineering, People's Republic of China) and PETER M. BAINUM (Howard University, Washington, DC). IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1319-1324. Research supported by NASA and Howard University. refs

Copyright

General motion equations in compact form using dyadic notation are developed for an orbiting flexible body of arbitrary shape. The equations are applied to three typical flexible space systems: a flexible beam, a flexible plate, and a flexible shallow spherical shell in orbit. The inertia dyadic of these flexible bodies may be calculated using the equations which have been obtained. R.B.

**A89-38207**

**A FORMULATION FOR STUDYING DYNAMICS OF FLEXIBLE STRUCTURES WITH APPLICATION TO WISP EXPERIMENT**

A. M. IBRAHIM and V. J. MODI (British Columbia, University, Vancouver, Canada). IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1325-1330.

Copyright

A methodology for formulating equations of motion applicable to a large class of systems with interconnected flexible deployable members is briefly outlined. Effectiveness of the formulation is illustrated through its application to a problem of contemporary interest, the WISP (Waves In Space Plasma) dipole antenna aboard the Space Shuttle. The parametric study suggests that under critical combinations of parameters, the system is susceptible to instability. The information is fundamental to the planning of the WISP experiment. Author

**A89-38864**

**SIMPLIFICATIONS USING ISOPARAMETRIC ELEMENTS IN FLEXIBLE LINKAGE ANALYSIS**

MARCO GIOVANNONI (Udine, Università, Italy). International Journal for Numerical Methods in Engineering (ISSN 0029-5981), vol. 26, April 1989, p. 967-977. refs

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This paper concerns finite element techniques applied to the analysis of mechanisms where a rigidity hypothesis for the links is unacceptable. Isoparametric elements may simplify the resulting equations because a good many of the terms arising from derivatives of rotation matrices disappear. Furthermore, the isoparametric approach leads to element matrices where integrations over element volumes do not depend on the gross motion of the linkage. Author

**A89-39151\*** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**QUASISTATIC SHAPE ADJUSTMENT OF A 15-METER-DIAMETER SPACE ANTENNA**

W. KEITH BELVIN, CATHERINE L. HERSTROM (NASA, Langley Research Center, Hampton, VA), and HAROLD H. EDIGHOFFER (Edighoffer, Inc., Newport News, VA). (Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987, Technical Papers, Part 1, p. 705-713) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 26, May-June 1989, p. 129-136. Previously cited in issue 14, p. 2115, Accession no. A87-33633. refs

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**A89-39152\***

**INFLUENCE OF TEMPERATURE ON STRUCTURAL JOINTS WITH DESIGNED-IN DAMPING**

JACKY C. PRUCZ (West Virginia University, Morgantown), LAWRENCE W. REHFELD (Georgia Institute of Technology, Atlanta), AMBUR D. REDDY (Lockheed-Georgia Co., Marietta), and PHILIP SMITH. Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 26, May-June 1989, p. 137-144. refs (Contract F49620-83-C-0017)

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An innovative means to enhance the inherent damping in structures is provided by the designed-in incorporation of viscoelastic materials in joints. The joints, as envisioned, are double-lap shear joints that dissipate energy when worked in an axial direction. The damping and stiffness characteristics of such joints have been evaluated experimentally at various temperatures and frequencies that are expected to be representative for large space structures. A new, nonresonant experimental technique has been utilized for this investigation. It provides the complex stiffness of the test specimen at extremely low strain levels, and accounts for elastic deformations in the test setup by means of carefully measured calibration factors. The temperature and frequency variations of the overall joint properties follow, in general, the same trends as the corresponding properties of the particular

### 03 STRUCTURAL CONCEPTS

viscoelastic material used in the joint. The test data show that properly selected viscoelastic materials and design configurations can reduce the dependence of the joint properties on temperature and frequency variations. Significant damping benefits are possible without unacceptable stiffness penalties. Author

#### A89-40453

##### **STABILIZATION OF FLEXIBLE STRUCTURES; PROCEEDINGS OF THE COMCON WORKSHOP, MONTPELLIER, FRANCE, DEC. 11-15, 1987**

A. V. BALAKRISHNAN, ED. (California, University, Los Angeles) and JEAN PAUL ZOLESIO, ED. (Montpellier II, Université, France) Workshop organized by ComCon Conference Board; Sponsored by CNRS, Ecole Nationale Supérieure des Mines de Paris, Institut National de Recherche en Informatique, et en Automatique, et al. Los Angeles, CA, Optimization Software, Inc., 1988, 314 p. For individual items see A89-40454 to A89-40468. Copyright

Various papers on the stabilization of flexible structures are presented. Individual topics considered include: a theory of nonlinear damping in flexible structures, estimation of Boltzmann damping coefficients in beam models, stabilization of vibrating beams by a specific feedback, boundary control problem for a parabolic equation in noncylindrical domain, dynamical control and design of flexible structures, presentation of the CNES and stabilization of flexible structure, general multiplier rule for infinite dimensional optimization problems with constraints, point stabilizers for dynamic structures, and destabilization of a vibrating beam by introduction of an observation delay. Also discussed are: recent results on control and stabilization of flexible structures, stabilization of a vibrating beam, random field estimation approach to multibody dynamics, spatially recursive filtering and smoothing for multibody dynamics, self-stabilization of damped flexible structures, and wave equation in time periodical domain. C.D.

#### A89-40454

##### **A THEORY OF NONLINEAR DAMPING IN FLEXIBLE STRUCTURES**

A. V. BALAKRISHNAN (California, University, Los Angeles) IN: Stabilization of flexible structures; Proceedings of the ComCon Workshop, Montpellier, France, Dec. 11-15, 1987. Los Angeles, CA, Optimization Software, Inc., 1988, p. 1-12. refs. Copyright

A class of nonlinear damping models for infinite dimensional hyperbolic systems is introduced. The models have application to flexible structures characterized by low damping. The basic formulation for modal response is presented, and the generalization to the continuum model where existence and uniqueness of solution to the abstract hyperbolic equations are proved for a restricted class of nonlinear damping models. The Krylov-Bogoliubov approximation to the modal response shows good qualitative agreement with experimental data. C.D.

A89-40455\* National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

##### **ESTIMATION OF BOLTZMANN DAMPING COEFFICIENTS IN BEAM MODELS**

H. T. BANKS (NASA, Langley Research Center; Institute for Computer Applications in Science and Engineering, Hampton, VA; Brown University, Providence, RI), R. H. FABIANO, and Y. WANG (Brown University, Providence, RI) IN: Stabilization of flexible structures; Proceedings of the ComCon Workshop, Montpellier, France, Dec. 11-15, 1987. Los Angeles, CA, Optimization Software, Inc., 1988, p. 13-35. refs. (Contract NSF MCS-85-04316; NAG1-1517; F49620-86-C-0111; NAS1-18107) Copyright

A distributed parameter model of a flexible structure with Boltzmann type viscoelastic damping is discussed. A computational method for the estimation of the damping parameters is developed, and theoretical convergence results are given. An example is presented in which actual experimental data is used, demonstrating

the efficacy of the computational method and the plausibility of the model for predicting response in damped structures. Author

#### A89-40456

##### **STABILIZATION OF VIBRATING BEAMS BY A SPECIFIC FEEDBACK**

F. CONRAD (Nancy, Université, Vandoeuvre-les-Nancy, France) IN: Stabilization of flexible structures; Proceedings of the ComCon Workshop, Montpellier, France, Dec. 11-15, 1987. Los Angeles, CA, Optimization Software, Inc., 1988, p. 36-51. refs. Copyright

The stabilization of serially connected flexible beams by feedback point control is addressed. The stabilizing effect is analyzed with respect to the feedback coefficients. The significance of the finding to some open questions is considered. C.D.

#### A89-40459

##### **THEORY, DESIGNS AND APPLICATIONS OF POINT STABILIZERS FOR DYNAMIC STRUCTURES**

GOONG CHEN (Texas A & M University, College Station) IN: Stabilization of flexible structures; Proceedings of the ComCon Workshop, Montpellier, France, Dec. 11-15, 1987. Los Angeles, CA, Optimization Software, Inc., 1988, p. 117-143. refs. (Contract AF-AFOSR-87-0334) Copyright

Active and passive stabilizers play an extremely important role in the control and stabilization of modern large flexible space structures. In this paper, the second order wave equation and the fourth order Euler-Bernoulli beam equation are used as simple vibration models to illustrate the theory, designs, and applications of passive or active point stabilizers on dynamic structures. Author

#### A89-40460

##### **DESTABILIZATION OF A VIBRATING BEAM BY INTRODUCTION OF AN OBSERVATION DELAY**

J. LEBLOND (Paris, Ecole Nationale Supérieure des Mines, France) IN: Stabilization of flexible structures; Proceedings of the ComCon Workshop, Montpellier, France, Dec. 11-15, 1987. Los Angeles, CA, Optimization Software, Inc., 1988, p. 144-150. refs. Copyright

An Euler-Bernoulli equation for a beam which is clamped at an extremity and controlled by a point force at the other is considered. The observation is given by the transverse velocity at the controlled extremity by Chen et al. (1987). It was shown that, under some hypothesis on the feedback operator, the closed-loop system is well-posed and that its energy decays uniformly exponentially. It is shown here that this uniformly stable boundary scheme is destabilized by the introduction of a time delay in the observation. Author

#### A89-40461

##### **SOME RECENT RESULTS ON CONTROL AND STABILIZATION OF FLEXIBLE STRUCTURES**

WALTER LITTMAN and LAWRENCE MARKUS (Minnesota, University, Minneapolis) IN: Stabilization of flexible structures; Proceedings of the ComCon Workshop, Montpellier, France, Dec. 11-15, 1987. Los Angeles, CA, Optimization Software, Inc., 1988, p. 151-161. refs. (Contract NSF DMS-86-07687; AF-AFOSR-86-0088) Copyright

A string/point mass system and the simplified SCOLE model are discussed as physical models for the control and stabilization of flexible structures. It is shown that in both cases asymptotic stability without any specific decay rate can be achieved by feedback boundary stabilization. Inverse power decay in time can be guaranteed by assuming additional initial smoothness. The principle of uniform boundedness is applied to obtain a simpler proof of an earlier result on decay rates. C.D.

AB9-40462

**STABILIZATION OF A VIBRATING BEAM - A REGULARITY RESULT**

J. P. MARMORAT and J. LEBLOND (Paris, Ecole Nationale Supérieure des Mines, France) IN: Stabilization of flexible structures; Proceedings of the ComCon Workshop, Montpellier, France, Dec. 11-15, 1987. Los Angeles, CA, Optimization Software, Inc., 1988, p. 162-183. refs

Copyright

This paper establishes the existence and the regularity of solutions of an Euler-Bernoulli beam equation with unbounded input-output operators. It proves the exponential stability of the closed-loop system solution of an optimal control problem.

Author

AB9-40806

**MATERIALS DEVELOPMENTS FOR FUTURE AEROSPACE STRUCTURES**

G. DOREY (Royal Aerospace Establishment, Farnborough, England) Aerospace (UK) (ISSN 0305-0831), vol. 16, May 1989, p. 10-17. refs

Copyright

The avenues for progressive improvement of aerospace structural materials' mechanical, thermal, and environmental properties are discussed; the aircraft primary structure materials in question encompass polymer-matrix composites, monolithic light alloys based on Al and Ti, novel alloys based on rapid-solidification techniques, metal- and ceramic-matrix composites, and hybrid laminates in which thin alternating plies of alloy and fiber-reinforced polymer are used. Significant prospective improvements are noted in the life cycle/cost performance of Al-Li monolithic structures, as well as by SPF/DB manufacturing methods. The most promising areas are in fiber-reinforced composites of all three (polymer, metal, ceramic) matrix types.

O.C.

AB9-41883

**STRUCTURAL CONTROL OF A VARIABLE CROSS-SECTION BEAM BY DISTRIBUTED FORCES**

I. S. SADEK (North Carolina, University, Wilmington), J. C. BRUCH, JR., J. M. SLOSS (California, University, Santa Barbara), and S. ADALI (Natal, University, Durban, Republic of South Africa) Mechanics of Structures and Machines (ISSN 0890-5452), vol. 16, no. 3, 1988-1989, p. 313-333. refs

Copyright

The problem of optimally controlling vibrations of a beam with a variable cross-section, subject to various boundary conditions, is solved by formulating a maximum principle. The problem is posed as a multi-objective control problem in which functionals of displacement, velocity, and force make up the performance measure. Compromise solutions are sought within the framework of Pareto optimality, with a view toward minimizing dynamic response of the beam within a specified time and with a minimum expenditure of force. Explicit solutions are given for an example problem, the behavior of which is numerically studied. In particular, the effectiveness of the proposed control law and the effect of various problem parameters on vibration damping are evaluated. Relations between various objectives are studied by means of optimal tradeoff curves that provide a valuable tool for choosing the most suitable combination of objectives.

Author

AB9-42315

**DYNAMIC RESPONSE ANALYSIS OF NONLINEAR STRUCTURAL SYSTEMS SUBJECT TO COMPONENT CHANGES**

ANANT R. KUKRETI (Oklahoma, University, Norman) Computers and Structures (ISSN 0045-7949), vol. 32, no. 1, 1989, p. 201-212. refs

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In this paper a coupled base motion methodology is presented in which the response characteristics of an original nonlinear system are used for evaluating the response behavior of an altered system. The nonlinear dynamic system is divided into two subsystems: the unaltered 'support' and the 'branch' which is liable to change.

The subsystems are discretized using finite element method for spatial dependence and Lagrangian approach to describe the motion. The attachment points of the branch and support are termed as interface coordinates. A mass reduction transformation is used to relate the noninterface subsystem displacements to the interface displacements. This enables all nonlinearities (material and/or geometric) to be grouped together with external dynamic loads (called pseudo loads) and an 'assumed linear' stiffness matrix is used throughout the response analysis. The discrete coordinates of the assumed linear subsystems may be transformed to modal coordinates. An iterative technique is used to approximate the pseudo loads as a polynomial (linear or quadratic) on time subintervals, which can be made small to assure convergence.

Author

AB9-42348

**DYNAMIC ANALYSIS OF FLEXIBLE MULTI-BODY SYSTEMS USING MIXED MODAL AND TANGENT COORDINATES**

BIPIN CHADHA and OM PRAKASH AGRAWAL (Southern Illinois University, Carbondale, IL) Computers and Structures (ISSN 0045-7949), vol. 31, no. 6, 1989, p. 1041-1050. refs

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This paper presents a mixed modal and tangent coordinate technique for computer aided analysis of flexible mechanical systems whose components undergo large translations and large rotations. In this model the configuration of a flexible component is identified by using two sets of generalized coordinates, namely rigid body and elastic coordinates. The rigid body coordinates define the location and orientation of a body axis, whereas the elastic coordinates define the displacement field of a component with respect to its body axis. The elastic coordinates are introduced by using finite element discretization to model flexible components with complex geometries. A modal analysis technique is used to identify the elastic mode shapes and to eliminate insignificant higher frequency modes. An orthonormalization of constraint Jacobian matrix associated with rigid body coordinates is used to identify the rigid body tangent coordinates. The resulting modal and tangent coordinates are used to develop an automated numerical integration scheme to solve the system differential and algebraic equations. Two numerical examples are considered to show the feasibility of dynamic analysis of flexible mechanical systems using this scheme.

Author

AB9-43046#

**AN IDENTIFICATION METHOD OF MULTINPUT, MULTIOUTPUT LINEAR DYNAMICAL SYSTEMS FOR THE EXPERIMENTAL MODAL ANALYSIS OF MECHANICAL STRUCTURES**

H. KANO (Fujitsu, Ltd., Numazu, Japan) ASME, Transactions, Journal of Dynamic Systems, Measurement, and Control (ISSN 0022-0434), vol. 111, June 1989, p. 146-152. refs

Copyright

A parameter identification method is proposed that can be used to evaluate dynamic characteristics of mechanical structures modeled as multinput multioutput linear dynamical systems. The discrete transfer function matrix is identified in two steps, one for the denominator and the other for the numerators, where the model order is determined with the aid of a 'prediction' error function. The continuous counterpart is then obtained by herein developed formula that links discrete and continuous models, from which vibration modal parameters are derived. Finally, the method is applied to the data obtained from vibration experiments of a test structure, and verified its practical usefulness.

Author

AB9-43052# Texas Univ., Austin.

**PARAMETER ROBUST LINEAR-QUADRATIC-GAUSSIAN DESIGN SYNTHESIS WITH FLEXIBLE STRUCTURE CONTROL APPLICATIONS**

MINJEA TAHK and JASON L. SPEYER (Texas, University, Austin) (1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings, Volume 1, p. 386-392) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, July-Aug. 1989, p. 460-468. Research supported by NASA.



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Previously cited in issue 10, p. 1576, Accession no. A88-27319.  
refs

(Contract AF-AFOSR-84-0371)

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**A88-43053\*** # Duke Univ., Durham, NC.

#### COMPUTATIONAL COMPLEXITIES AND STORAGE REQUIREMENTS OF SOME RICCATI EQUATION SOLVERS

SENOL UTKU (Duke University, Durham, NC), JOHN A. GARBA (California Institute of Technology, Jet Propulsion Laboratory, Pasadena), and A. V. RAMESH (U.S. Army and USAF, Conference on Non-Linear Vibrations, Stability, and Dynamics of Structures and Mechanisms, Virginia Polytechnic Institute and State University, Blacksburg, Mar. 23-25, 1987) *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090), vol. 12, July-Aug. 1989, p. 469-479. refs

Copyright

The linear optimal control problem of an  $n$ th-order time-invariant dynamic system with a quadratic performance functional is usually solved by the Hamilton-Jacobi approach. This leads to the solution of the differential matrix Riccati equation with a terminal condition. The bulk of the computation for the optimal control problem is related to the solution of this equation. There are various algorithms in the literature for solving the matrix Riccati equation. However, computational complexities and storage requirements as a function of numbers of state variables, control variables, and sensors are not available for all these algorithms. In this work, the computational complexities and storage requirements for some of these algorithms are given. These expressions show the immensity of the computational requirements of the algorithms in solving the Riccati equation for large-order systems such as the control of highly flexible space structures. The expressions are also needed to compute the speedup and efficiency of any implementation of these algorithms on concurrent machines. Author

**A88-43064\*** # Old Dominion Univ., Norfolk, VA.

#### SINGLE-MODE PROJECTION FILTERS FOR MODAL PARAMETER IDENTIFICATION FOR FLEXIBLE STRUCTURES

JEN-KUANG HUANG, CHUNG-WEN CHEN (Old Dominion University, Norfolk, VA), and JER-NAN JUANG (NASA, Langley Research Center, Hampton, VA) *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090), vol. 12, July-Aug. 1989, p. 568-576. refs

(Contract NAG1-655)

Copyright

Single-mode projection filters are developed for eigensystem parameter identification from both analytical results and test data. Explicit formulations of these projection filters are derived using the orthogonal matrices of the controllability and observability matrices in the general sense. A global minimum optimization algorithm is applied to update the filter parameters by using the interval analysis method. The updated modal parameters represent the characteristics of the test data. For illustration of this new approach, a numerical simulation for the MAST beam structure is shown by using a one-dimensional global optimization algorithm to identify modal frequencies and damping. The projection filters are practical for parallel processing implementation. Author

**A88-43066\***

#### VIBRATION COMPENSATION IN OPTICAL TRACKING SYSTEMS

ENRIQUE BARBIERI (Tulane University, New Orleans, LA), UMIT OZGUNER, and STEPHEN YURKOVICH (Ohio State University, Columbus) *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090), vol. 12, July-Aug. 1989, p. 585-592. refs

Copyright

Modeling and control of multiple-mirror/flexible-slewing structures are considered. Primary applications for such systems include line-of-sight pointing systems on large flexible structures, space telerobotic systems, and space telescope systems. Analysis can be accomplished in a four-stage process: (1) relegation of control tasks; (2) flexible structure modeling and the slewing control problem; (3) vibration compensation using mirror actuators; and

(4) active vibration damping with additional (structural) actuation. In the present paper, the first and third stages of the process are addressed. Relegation is achieved under the assumption that the optical ray hits the center of the following mirror along the ray path. Vibration compensation is then cast into the framework of a decentralized servocompensator problem. A recently developed optimal solution approach is utilized. A particular system is examined in detail, and control simulations are included to illustrate the results. Author

**A88-43220\***

#### GRUMMAN PROTOTYPE SPACE ERECTABLE RADIATOR SYSTEM THERMAL TEST BED RESULTS

J. ALARIO, M. LEAGUE, F. GISONDO (Grumman Corp., Grumman Space Systems Div., Bethpage, NY), and M. HUTCHISON (Grumman Corp., Grumman Space Systems Div., Houston, TX) *AIAA, Thermophysics Conference*, 24th, Buffalo, NY, June 12-14, 1989, 10 p. refs

(AIAA PAPER 89-1704) Copyright

NASA-Johnson's space-erectable radiator system (SERS) employs modular, high-capacity radiator panels to yield long service-life, reliable waste heat-rejection capacity for Space Station Freedom and comparably large spacecraft. The prototype SERS employs monogroove heat pipe technology in its radiator element; the SERS ground-test article consists of eight SERS panels and eight separate whiffletree clamps. Thermal vacuum tests have been conducted in the test-bed facility on a single radiator panel and on a separate six-panel subsystem integrated with the condensers of a two-phase thermal bus. All performance requirements have been met or exceeded in both cases. O.C.

**A88-43717**

#### STRUCTURAL DESIGN AND VALIDATION CHALLENGES OF LARGE SPACE SYSTEMS

KETO SOOSAAR (Cambridge Research, MA) In: *Space - A new community of opportunity*; Proceedings of the Thirty-fourth Annual AAS International Conference, Houston, TX, Nov. 3-5, 1987. San Diego, CA, Univelt, Inc., 1989, p. 313-317.

(AAS PAPER 87-661) Copyright

Issues related to the design and validation of large space systems are discussed. The engineering aspects of design and validation process are reviewed. Consideration is given to the educational preparation of the engineer, the availability of suitable analysis and design tools, appropriate organizational structures for developing technologies, and long-term support to the development of large space systems. R.B.

**A88-43718**

#### LARGE SCALE COMPUTATIONAL ISSUES IN THE DYNAMICS OF LARGE SPACE STRUCTURES

EDWARD J. HAUG (Iowa, University, Iowa City) In: *Space - A new community of opportunity*; Proceedings of the Thirty-fourth Annual AAS International Conference, Houston, TX, Nov. 3-5, 1987. San Diego, CA, Univelt, Inc., 1989, p. 319-326.

(AAS PAPER 87-662) Copyright

Computational issues in the dynamics of space structures are discussed. Algorithms for multiflexible body dynamics, nonlinear deployment dynamics, remote manipulator systems, and parallel processor high speed computation are examined. The differences between the study of the dynamics of articulated structures and conventional finite element structural analysis are noted. R.B.

**A88-44292**

#### ATTITUDE STABILITY OF RIGID SATELLITES VIA A NORMALIZED HAMILTONIAN

S. R. MARANDI and V. J. MODI (British Columbia, University, Vancouver, Canada) *International Congress of Theoretical and Applied Mechanics*, 17th, Grenoble, France, Aug. 21-27, 1988) *Acta Astronautica* (ISSN 0094-5765), vol. 19, April 1989, p. 287-299. refs

Copyright

A breakthrough is made in the long outstanding problem of attitude stability of a rigid satellite in a circular orbit. The focus is

on an equilibrium at which the linearized techniques are inconclusive and no Liapunov function is known. In this paper, the Hamiltonian for the attitude motion of the satellite is expanded about the equilibrium up to the terms of degree four. By a sequence of canonical transformations, the expansion is brought to a normal form. A region in the parameter space for which the equilibrium orientation is stable is demarcated by an application of a recent extension of KAM theory to the normal form of Hamiltonians. This approach resolves the question and opens the door for the stability analysis of higher order conservative systems, such as flexible satellites, not amenable to traditional tools. Author

**A89-45726 BDM Corp., Albuquerque, NM.**  
**ENGINEERING, CONSTRUCTION, AND OPERATIONS IN SPACE; PROCEEDINGS OF THE SPACE '88 CONFERENCE, ALBUQUERQUE, NM, AUG. 29-31, 1988**

STEWART W. JOHNSON, ED. and JOHN P. WETZEL, ED. (BDM Corp., Albuquerque, NM) Conference sponsored by ASCE, AIAA, NASA, et al. New York, American Society of Civil Engineers, 1988, 1363 p. For individual items see A89-45727 to A89-45835. Copyright

The broad topics considered are extraterrestrial basing, the Space Station and orbiting structures, and areas of special interest. The section on extraterrestrial basing considers the processing of lunar soils, lunar surface construction and operations, lunar base design, and Martian basing. The section on the Space Station and orbiting structures considers the mechanics of space structures and materials, space environmental effects, robotic construction and planning, and maintenance and operations associated with the Space Station. Areas of special interest include space power, life support systems, human factors, astronomy, education, and management and planning of systems for space facilities. B.J.

**A89-45765\* North Carolina Agricultural and Technical State Univ., Greensboro.**

**DYNAMIC ANALYSIS OF THE JOINT DOMINATED BEAM**  
 ELIAS G. ABU-SABA, ARCHIBALD N. SHERBOURNE (North Carolina Agricultural and Technical State University, Greensboro), and RAYMOND C. MONTGOMERY (NASA, Langley Research Center, Hampton, VA) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 495-505. (Contract NAG1-405) Copyright

A method for determining the vibrational modes of the joint dominated beam is presented with reference to space erectable structures. Mathematical models with and without joint imperfection are developed. Joint imperfection is represented by a simple flexibility,  $k$ , in the axial direction of the chord members only. An interactive computer program is used to obtain eigenvalue characteristics and mode shapes of the system. Results are presented on frequencies of the given truss beam with and without joint imperfections for three-panel and 10-panel models. Also presented are results of parametric studies of the beam truss models of three and 10 panels with  $k = 0.05, 0.10, 0.50$ , and  $1.0 \times 10$  to the -7th. B.J.

**A89-45766**  
**FATIGUE RELIABILITY OF SPACE STRUCTURES**

RICHARD J. NIELSEN (Idaho, University, Moscow) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 529-539. refs (Contract NSF CES-87-07789) Copyright

A methodology for calculating the probability distribution for rainfall cycles in a nonstationary Gaussian process is developed which is suited for fatigue life prediction for transient vibratory loads of interest in space structures. The up and down crossing rates are estimated for the process; the level-crossing statistics are then used to determine the waiting time for range-pair

exceedances. The waiting time distribution for the rainfall cycles is derived from the range-pair distribution. Finally, the probability distribution for the rainfall cycles is calculated from the waiting time distribution. B.J.

**A89-45771**  
**INFLATABLE FORM CONSTRUCTION IN SPACE**

RICHARD A. KADEN (U.S. Army, Corps of Engineers, Wella Walla, WA) and LEONARD D. PENSE (TREE, Inc., Oklahoma City, OK) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 564-574. Copyright

The innovative use of a double-walled inflatable form (IF) for constructing temporary or low-cost 'disposable' structures is discussed. IFs may serve as bulk cargo storage, exercise rooms, low-tech space laboratory or experimental areas, and waste tanks. With advances in flexible membranes, IF modules may be either taken into space as material containers or built in space. It is suggested that a construction cluster may be assembled in space from module containers; the docking port frame would be attached to the support cluster and inflated. IF structures in a wide variety of shapes (sphere, ellipsoid, cylinder, and segmented torus) are discussed. B.J.

**A89-45774**  
**CONTAINERLESS COATING PROCESSES FOR LARGE SPACE STRUCTURES**

L. D. STEPHENSON, A. SMITH, V. F. HOCK (U.S. Army, Construction Engineering Research Laboratory, Champaign, IL), and J. M. RIGSBEE (Illinois, University, Urbana) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 595-606. refs Copyright

Large space structures (LSS) in low earth orbit (LEO) must be able to withstand the deleterious effects of in situ ultraviolet radiation, atomic oxygen, and thermal-cycling-induced micro-cracking. Protective coatings to be applied in space using containerless coating technology can be expected to mitigate these problems. Such coating systems are based on exploitation of the inherent vacuum levels available in LEO by employing any combination of metal vapor deposition, ion and neutral beam implantation, or ion beam mixing techniques. A series of proof-of-concept containerless coating experiments are being planned for space flight in the early 1990's. It is believed that the space-based containerless coating techniques to be developed from those experiments will eventually play a major role in the construction, maintenance, and repair of previously erected/deployed military space structures. Author

**A89-45787**  
**PLANAR SPACE STRUCTURES**

M. J. IREMONGER, T. S. LOK (Royal Military College of Science, Shrivenham, England), and M. E. A. PASSMORE IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 762-773. Copyright

The planar construction system for the development of space structures is examined. The system uses relatively thin materials folded into interpenetrated triangular units in a closed section. The methods of manufacturing and assembling planar space structures are presented. Also, an alternative slotted core system is described, which has more efficient load distribution within the structure. Examples of possible structures that could be developed using the planar system are given, including an alternative space station concept. R.B.

**A89-45834**  
**ASTROTECTONICS - AN OVERVIEW**

THOMAS M. CIESLA (Outer Space Environments, Spring, TX) IN: Engineering, construction, and operations in space; Proceedings

### 03 STRUCTURAL CONCEPTS

of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 1320-1330. refs

Copyright

Astroflectonics is the science of construction in space of both orbital and planetary structures and facilities, as well as orbitally assembled interplanetary spacecraft. The success of man's construction activities is dependent on the development of support equipment and assembly techniques using man alone, man and robotics, or robotics alone, depending on the work to be performed and the hazards present. The separation of Astroflectonics into distinct genres of orbital and planetary facility construction due to subtle differences in the environment and subsequently, the equipment, is discussed. Author

**A88-48084**

#### **SOLVING THE PROBLEM OF JOINING COMPOSITE STRUCTURES IN SPACE**

Aerospace Engineering (ISSN 0736-2536), vol. 9, July 1989, p. 9-11.

Copyright

The use of pultrusion and induction bonding as potential methods for manufacturing large structures made of advanced composite materials is discussed. As compared to conventional manufacturing techniques, the pultrusion method has very low labor and equipment requirements. It is found that a combination of earth-based prefabrication of fiber-reinforced thermoplastic coiled stock, postfabrication in space using pultrusion technology, and the joining of structural members by toroid plastic welding is a viable approach to manufacturing large space platforms. K.K.

**A88-46536\*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

#### **CONSTRUCTION OF LARGE SPACE POWER FACILITIES**

LYLE M. JENKINS (NASA, Johnson Space Center, Houston, TX) (IAF, International Conference on Space Power, Cleveland, OH, June 5-7, 1989) Space Power (ISSN 0951-5089), vol. 8, no. 3, 1989, p. 379-388. refs

(IAF PAPER ICOSP89-12-2) Copyright

Construction was an important facet of the Satellite Power System studies in the late 1970s. Satellite servicing and assembly of the Space Station Freedom are addressing many of the critical issues in construction of large space systems. Design for assembly, capability of construction equipment and interaction with the launch system influence configuration development. The extravehicular capabilities of space-suited crew and remote operating systems like the Flight Telerobotic Servicer will provide an operational experience base for development of future large space power facilities. Economics success may well depend on early consideration of construction requirements and capabilities.

Author

**A88-47715#**

#### **CONVERGENCE PROPERTIES OF MODAL COSTS FOR CERTAIN DISTRIBUTED PARAMETER SYSTEMS**

A. HU (Dynacs Engineering Co., Clearwater, FL) and R. E. SKELTON (Purdue University, West Lafayette, IN) ASME, Transactions, Journal of Vibration, Acoustics, Stress, and Reliability in Design (ISSN 0739-3717), vol. 111, July 1989, p. 272-277. refs

Copyright

A complete modal cost analysis is presented for the vibration of various kinds of simple continua with different boundary conditions. Explicit formulas for the total cost are derived for these distributed parameter systems. The convergence theorems developed are useful in the model reduction of the equivalent continuum models of large space structures as well as in the selection of finite element code for control design. Author

**A88-48564#**

#### **DELAMINATION-BASED APPROACH TOWARD FRACTURE CONTROL OF COMPOSITE SPACECRAFT STRUCTURES**

C. K. H. DHARAN (California, University, Berkeley) (IAF,

International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1989, IAF Paper 88-282) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 26, July-Aug. 1989, p. 229-233. Research supported by the Solar Energy Research Institute. Previously cited in issue 24, p. 3924, Accession no. A88-55374. refs

(Contract DE-AC02-83CH-10093)

Copyright

**A88-48640**

#### **STRUCTURAL ANALYSIS AND DESIGN OF DEPLOYABLE STRUCTURES**

CHARIS J. GANTES, JEROME J. CONNOR, ROBERT D. LOGCHER (MIT, Cambridge, MA), and YECHIEL ROSENFELD (Technion - Israel Institute of Technology, Haifa) Computers and Structures (ISSN 0045-7949), vol. 32, no. 3-4, 1989, p. 661-669. refs

Copyright

Deployable-collapseable structures have many potential applications ranging from emergency shelters and facilities, through relocatable, semi-permanent structures, to space-station components. During the deployment phase, these structures exhibit a highly nonlinear behavior. A large-displacements/small-strains finite-element formulation is used to trace the nonlinear load-displacement curve, and to obtain the maximum internal forces that occur in the members of the structure during deployment. The influence of various parameters that affect the behavior of the structures, such as geometric shape, dimensions of the members, cross-sectional properties, and kinematic assumptions is investigated. Author

**A88-48769**

#### **ON-ORBIT FABRICATION OF SPACE STATION STRUCTURES**

JONATHAN COLTON, JED LYONS, BOB LUKASIK, JOHN MAYER, STEFAN WITTE (Georgia Institute of Technology, Atlanta) et al. SAMPE Quarterly (ISSN 0036-0821), vol. 20, July 1989, p. 9-14. refs

Copyright

A novel mold-less processing technique has been developed which uses gas pressure and bladders to produce tubular structural members out of which one can construct space truss structures. A woven or braided prepreg preform is produced on earth and brought into orbit. Integral to the preform is an inner bladder which contains the gas pressure used in consolidation, and an outer layer which produces the counter-force needed for consolidation. Solar heating is used in conjunction with the gas to process the preforms into the final parts. This technique allows for the most efficient use of resources while providing for the flexible production of a wide-size range of structures. Author

**A88-50151**

#### **VIBRATION ANALYSIS OF HYSTERETICALLY DAMPED MASS-LOADED BEAMS**

D. N. MANIKANAHALLY and M. J. CROCKER (Auburn University, AL) Journal of Sound and Vibration (ISSN 0022-460X), vol. 132, July 22, 1989, p. 177-197. Research supported by Auburn University and SDIO. refs

(Contract DNA001-85-C-0183)

Copyright

A procedure for determining the dynamic displacement and dynamic strain of a hysteretically damped mass-loaded free-free beam, subjected to simple harmonic, half-sine pulse and white noise excitations, is presented. Although free-free beams are considered in the analysis, the same procedure could also be used for vibration analysis of mass-loaded beams with other end conditions. The mode shapes for free vibration, displacement and strain due to simple harmonic and half-sine pulse force excitation are presented in graphical form. The maximum mean square displacement and mean square strain are tabulated for Gaussian white noise excitation. The analysis is used to analyze a space structure, which was modeled as a mass-loaded free-free beam. An exhaustive optimization search was made to obtain a structure with minimum dynamic response, when it is subjected to simple



harmonic and half-sine pulse force excitations and minimum mean square response when subjected to Gaussian white noise excitation. Author

**A89-50543#**

**CONTINUUM MODELING OF FLEXIBLE STRUCTURES WITH APPLICATION TO VIBRATION CONTROL**

W. H. BENNETT and H. G. KWATNY (Techno-Sciences, Inc., Greenbelt, MD) *AIAA Journal* (ISSN 0001-1452), vol. 27, Sept. 1989, p. 1264-1273. Previously cited in issue 07, p. 659, Accession no. A86-19733. refs (Contract F49620-84-C-0115) Copyright

**A89-50615\*#** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

**PULTRUSION WITH THERMOPLASTICS FOR THE FABRICATION OF STRUCTURES IN SPACE**

MAYWOOD L. WILSON, IAN O. MACCONOCHIE, and GARY S. JOHNSON (NASA, Langley Research Center, Hampton, VA) *SAWE, Annual Conference*, 47th, Plymouth, MI, May 23-25, 1988. 14 p. refs (SAWE PAPER 1819)

The use of the pultrusion method to produce structures in space is proposed. This technique is based on transporting materials in coils or bundles and fabricating the structures in space. Two methods for thermoplastic impregnation of advanced composite are described. The properties of three pultruded thermoplastic matrix materials, polyphenylene sulfide, polyetherimide (PEI), and polysiloxetheretherketone (PEEK) are discussed and evaluated. It is observed that the pultrusions containing PEI and PEEK reveal post-fabrication potential of lightweight, high strength advanced composites and this method of fabrication produces strength values comparable to those of conventional techniques. Earth-based and space-based planetary shelter models are developed and compared. It is noted that cargo storage volume is dependent on a combination of profiles, packaging, and manufacturing methods. I.F.

**A89-51132**

**INFLATABLE, SPACE RIGIDIZED STRUCTURES - AGING AND THERMAL CYCLING IMPACT**

M. C. BERNASCONI (Contraves AG, Zurich, Switzerland) and W. SEIZ (Ciba-Geigy AG, Marly, Switzerland) *IN: European Symposium on Spacecraft Materials in Space Environment*, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 507-518. Sponsorship: European Space Research and Technology Centre. (Contract ESTEC-4023/79/NL/AK; ESTEC-5505/83/NL/PB) Copyright

A four-year test was performed to determine the consequences of heat aging at 75, 105, and 135 C on a Kapton/Kevlar laminate. Three matrix resins and two reinforcement materials were tested. The material with a matrix resin consisting of a polyimide-modified cycloaliphatic epoxy was found to remain largely unaffected by a four-year exposure at 105 C. Two different thermal cycle tests have been conducted using rigidized samples which are representative of all the combination of materials and seams near the rim of an ISRS reflector. Microscopic inspection results and mechanical property data are presented. R.R.

**A89-51711#**

**SQUARE-ROOT STATE ESTIMATION FOR SECOND-ORDER LARGE SPACE STRUCTURES MODELS**

YAAKOV OSHMAN, DANIEL J. INMAN (New York, State University, Buffalo), and ALAN J. LAUB (California, University, Santa Barbara) *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090), vol. 12, Sept.-Oct. 1989, p. 696-708. Previously cited in issue 22, p. 3550, Accession no. A87-50473. refs (Contract NSF MEA-81-10225; AF-AFOSR-82-0242; NSF ECS-84-06152) Copyright

**A89-51722\*#** SDRC, Inc., San Diego, CA.

**CALCULATION OF STRUCTURAL DYNAMIC FORCES AND STRESSES USING MODE ACCELERATION**

PAUL BLELLOCH (SDRC, Inc., San Diego, CA) *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090), vol. 12, Oct. 1989, p. 760-762. Copyright

While the standard mode acceleration formulation in structural dynamics has often been interpreted to suggest that the reason for improved convergence obtainable is that the dynamic correction factor is divided by the modal frequencies-squared, an alternative formulation is presented which clearly indicates that the only difference between mode acceleration and mode displacement data recovery is the addition of a static correction term. Attention is given to the advantages in numerical implementation associated with this alternative, as well as to an illustrative example. O.C.

**A89-52564\*#** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

**INTEGRATED STRUCTURE/CONTROL LAW DESIGN BY MULTILEVEL OPTIMIZATION**

MICHAEL G. GILBERT (NASA, Langley Research Center, Hampton, VA) and DAVID K. SCHMIDT (Arizona State University, Tempe) *IN: AIAA Guidance, Navigation and Control Conference*, Boston, MA, Aug. 14-18, 1989, Technical Papers, Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 376-385. Previously announced in STAR as N89-26623. refs (AIAA PAPER 89-3470) Copyright

A new approach to integrated structure/control law design based on multilevel optimization is presented. This new approach is applicable to aircraft and spacecraft and allows for the independent design of the structure and control law. Integration of the designs is achieved through use of an upper level coordination problem formulation within the multilevel optimization framework. The method requires the use of structure and control law design sensitivity information. A general multilevel structure/control law design problem formulation is given, and the use of Linear Quadratic Gaussian (LQG) control law design and design sensitivity methods within the formulation is illustrated. Results of three simple integrated structure/control law design examples are presented. These results show the capability of structure and control law design tradeoffs to improve controlled system performance within the multilevel approach. Author

**A89-52578#**

**GIBBS PHENOMENON IN STRUCTURAL CONTROL**

H. BARUH and S. S. K. TADIKONDA (Rutgers University, New Brunswick, NJ) *IN: AIAA Guidance, Navigation and Control Conference*, Boston, MA, Aug. 14-18, 1989, Technical Papers, Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 510-518. refs (AIAA PAPER 89-3485) Copyright

Existence of the Gibbs phenomenon during control of flexible structures is investigated. It is shown that either due to the choice of the actuation mechanisms as point of piecewise-continuous components or due to the time history of the external excitation, discontinuities may exist in the spatial and temporal profiles of the control input. A spatial eigenfunction expansion of the control profile and a Fourier series expansion of the temporal behavior indicates the Gibbs effect. The consequence of having a Gibbs effect is the excitation of residual dynamics with higher amplitudes and generation of undesirable motion. Discrete actuation mechanisms such as point forces, piecewise-continuous forces and point torques are compared with respect to how much they excite the residual dynamics. Author

**A89-52621#**

**OPTIMAL AND SUBOPTIMAL ESTIMATION APPLIED TO LARGE FLEXIBLE STRUCTURES**

B. K. WALKER (Cincinnati, University, OH) and S. M. DUMBACHER *IN: AIAA Guidance, Navigation and Control Conference*, Boston, MA, Aug. 14-18, 1989, Technical Papers, Part

2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 921-931. refs  
(AIAA PAPER 89-3533) Copyright

A comparison of optimal and suboptimal estimation applied to large flexible structures under imperfect model information conditions is presented. The filters estimate the modal positions and velocities of a simple pinned-pinned beam. Among the types of estimators investigated are full and reduced-order centralized estimators, reduced-order decentralized estimators, and one-mode and two-mode sensitivity-shaped estimators. The suboptimal estimators are shown to have lower position rms error values than the optimal estimator when 20 percent errors in the structural frequencies are present. The sensitivity-shaped estimators produce more accurate position estimates when velocity sensors are used than any of the reduced-order Linear Quadratic (LQ) centralized or decentralized estimators. A method for choosing the gains of the sensitivity-shaped estimators is given. Author

**A89-52650\*** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

#### **A SURVEY OF EXPERIMENTS AND EXPERIMENTAL FACILITIES FOR CONTROL OF FLEXIBLE STRUCTURES**

DEAN W. SPARKS, JR., JER-NAN JUANG (NASA, Langley Research Center, Hampton, VA), and GERHARD J. KLOSE (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1176-1185. refs  
(AIAA PAPER 89-3567) Copyright

This paper presents a survey of U.S. ground experiments and facilities dedicated to the study of active control of flexible structures. The facilities will be briefly described in terms of capability, configuration, size and instrumentation. Topics on the experiments include vibration suppression, slewing and system identification. Future research directions, particularly of the NASA Langley Research Center's Controls/Structures Interaction (CSI) ground test program, will be discussed. Author

#### **A89-52651# IDENTIFICATION OF THE TENDON CONTROL SYSTEM FOR FLEXIBLE SPACE STRUCTURES**

YOSHISADA MUROTSU, HIROSHI OKUBO, and KEI SENDA (Osaka Prefecture University, Sakai, Japan) IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1186-1194. refs  
(AIAA PAPER 89-3568) Copyright

An experimental tendon control system is identified to make an accurate mathematical model for designing a good controller. The experimental tendon control system has been built for the vibration control of a flexible beam simulating Large Space Structures (LSS). This system has many natural vibration modes of low frequency. So, it needs much time to carry out a modal survey test. A proposed scheme needs time histories of responses for a very short period. First, a mathematical model of the system is developed through a finite element method (FEM). Second, unknown characteristic parameters are estimated by using an output error method. The validity of the proposed scheme is demonstrated by good agreement between the transfer functions of the experimental system and an identified model. Finally, the accuracy of the identified model is also verified by the agreement between the computed and the experimental closed-loop responses. Author

**A89-52652\*** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

#### **MODEL REDUCTION FOR FLEXIBLE STRUCTURES - TEST DATA APPROACH**

WODEK GAWRONSKI (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical

Papers, Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1195-1199. refs  
(AIAA PAPER 89-3569) Copyright

A reduced model of a system is obtained by truncating part of its state variables. Hankel singular values and component costs determine which component is deleted or retained in the reduced model. In this paper Hankel singular values and component costs of a flexible structure are obtained from the resonance test data, rather than from the system matrices. Test data, besides system dynamics, include also actuators and sensors dynamics. For this reason, the reduced model obtained from test data can be far from the optimal one. In this paper the reconstruction of the flexible structure indices from the joint actuator-sensor-flexible structure indices is discussed. Author

**A89-52653\*** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

#### **OPTIMAL DECENTRALIZED FEEDBACK CONTROL FOR A TRUSS STRUCTURE**

A. CAGLE (NASA, Langley Research Center, Hampton, VA; Ohio State University, Columbus) and U. OZGUNER (Ohio State University, Columbus) IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1200-1206. refs  
(Contract F33615-87-C-3257)  
(AIAA PAPER 89-3570) Copyright

One approach to the decentralized control of large flexible space structures involves the design of controllers for the substructures of large systems and their subsequent application to the entire coupled system. This approach is presently developed for the case of active vibration damping on an experimental large truss structure. The isolated boundary loading method is used to define component models by FEM; component controllers are designed using an interlocking control concept which minimizes the motion of the boundary nodes, thereby reducing the exchange of mechanical disturbances among components. O.C.

#### **A89-52714# WAVE-ABSORBING CONTROL FOR FLEXIBLE SPACE STRUCTURES WITH NON-COLOCATED SENSORS AND ACTUATORS**

HIRONORI FUJII, TOSHIYUKI OHTSUKA, and TSUTOMU MURAYAMA (Tokyo Metropolitan Institute of Technology, Hino, Japan) AIAA, Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, 7 p. refs  
(AIAA PAPER 89-3537) Copyright

A design concept of wave-absorbing controllers with noncollocated sensors and actuators is presented. Flexible structures are modeled as networks of one-dimensional media which transmit traveling waves. External control forces are applied at junctions to control the boundary conditions of the system's governing partial differential equations. The advantages of describing the model dynamics in terms of propagating disturbances are discussed. K.K.

#### **A89-53123 FINITE ELEMENT ANALYSIS OF MANEUVERING SPACECRAFT TRUSS STRUCTURES**

E. R. CHRISTENSEN (Auburn University, AL) Computers and Structures (ISSN 0045-7949), vol. 32, no. 6, 1989, p. 1403-1411. refs  
Copyright

A finite element modeling and solution technique capable of determining the time response of flexible spacecraft truss structures undergoing large angle slew maneuvers has been developed. The elastic deformations of the structure are coupled with large nonsteady translational and rotational motions with respect to an inertial reference frame. The governing equations of motion of the system are derived using momentum conservation principles and the principle of virtual work. The finite element approximation is applied to the equations of motion and the resulting set of nonlinear second order matrix differential equations is solved timewise by



an iterative direct numerical integration scheme based on the trapezoidal rule. The solution technique is tested on both planar and three-dimensional maneuvering spacecraft truss structures.

Author

AB-53674

**DESIGN OF HIGH STIFFNESS AND LOW CTE THERMOPLASTIC COMPOSITE SPACECRAFT STRUCTURES**

EDWARD M. SILVERMAN, JANE E. SATHOFF, and WILLIAM C. FORBES (TRW, Inc., TRW Space and Technology Group, Redondo Beach, CA) SAMPE Journal (ISSN 0091-1062), vol. 25, Sept.-Oct. 1989, p. 39-46.

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The use of thermoplastic matrix composites in spacecraft applications where stiffness and CTE requirements are dominant is discussed. It is noted that the incorporation of high-modulus 517.5 GPa pitch-based graphite fibers into a thermoplastic PEEK matrix leads to properties that make it possible for spacecraft designers to achieve maximum stiffness in structures with near-zero coefficients of thermal expansion. The properties of several symmetric angle-ply laminates composed of the unidirectional P75/PEEK prepreg tape and the commingled woven P75/PEEK fabric product forms are studied.

K.K.

AB-53936#

**BUCKLING AND POSTBUCKLING OF LAMINATED COMPOSITE PLATES WITH PLY DROPOFFS**

MARC T. DINARDO and PAUL A. LAGACE (MIT, Cambridge, MA) (Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987, Technical Papers, Part 1, p. 156-164) AIAA Journal (ISSN 0001-1452), vol. 27, Oct. 1989, p. 1392-1398. Research supported by Boeing Military Airplanes Co. Previously cited in issue 14, p. 2165, Accession no. A87-33569.

refs

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AB-53954

**ELASTICALLY COUPLED PRECISION POINTING BY SLEW-INDUCED DEFORMATION SHAPING**

THOMAS A. W. DWYER, III and JOHN R. HOYLE, JR. (Illinois University, Urbana) IN: 1989 American Control Conference, 8th, Pittsburgh, PA, June 21-23, 1989, Proceedings, Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 48-53. Research supported by SDIO. refs

(Contract F49620-87-C-0103)

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Computed torques for pointing and tracking require compensation for slew-induced structural, forebody/afterbody, or optical train alignment deformations. Thus, even if only line-of-sight variables are to be commanded, full state feedback is needed, with consequent high bandwidth control requirements. The solution investigated in this study is to decouple the unwanted deformation state by feedforward of the line-of-sight slew dynamics into the deformation control forces or moments, for an apparatus consisting of a mirror mounted on an optical bench that is itself mounted on a rotated table. Adjustable elastic interfaces are used to model slew-induced deformations as angular differences between mirror mounting, optical bench, and rate table. Low bandwidth control with fewer actuators than degrees of freedom is shown to be possible by correcting the computed torques so as to force the interstage angular differences (standing for slew-induced deformations) to evolve in a slow integral manifold wherein they are modeled as functions of the mirror pointing angle. Simultaneous mirror pointing and independent rate table pointing are also shown to be possible, which represents the situation of pointing an instrument elastically mounted on a maneuvering platform. I.E.

AB-54012

**ROBUST CONTROL FOR RAPID REORIENTATION OF FLEXIBLE STRUCTURES**

O. AKHRIF, G. L. BLANKENSHIP, and W. H. BENNETT (Techno-Sciences, Inc., Greenbelt, MD) IN: 1989 American Control Conference, 8th, Pittsburgh, PA, June 21-23, 1989, Proceedings.

Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 1142-1147. Research supported by SDIO.

(Contract F33615-87-C-0103)

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Consideration is given to the practical application of methods for feedback linearization of multibody systems with elastic interactions. The authors investigate the role of singular perturbation analysis for the design of nonlinear control for rapid slewing of a rigid body with attached flexible appendage. Similar problems arise in elastic models for appendage deployment and fast, lightweight robotic arms. Although such models cannot be exactly linearized by C-inf transformation of the system state and feedback, the nominal models can be partially linearized with respect to primary system orientation variables. Models are developed, and various options for robust control implementation are discussed. I.E.

AB-54018

**ISOLATION OF A VIBRATING MACHINE MOUNTED ON A FLEXIBLE STRUCTURE**

LISA A. SIEVERS, ANDREAS H. VON FLOTOW, and KELVIN B. SCRIBNER (MIT, Cambridge, MA) IN: 1989 American Control Conference, 8th, Pittsburgh, PA, June 21-23, 1989, Proceedings, Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 1182-1188. refs

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The authors consider the problem of actively isolating a vibrating machine from a flexible structure. The structural dynamic response is assumed to be known with too little fidelity to permit model-based control design. The discussion is specialized to narrowband disturbances and to single-axis mounting. Narrowband compensation, based on knowledge of the disturbance frequency, is proposed. Guaranteed properties of the structural dynamic response are exploited to derive stability and maximum performance criteria for this type of compensation. I.E.

AB-54021

**A NEW SYSTEM IDENTIFICATION TECHNIQUE FOR HARMONIC DECOMPOSITION WITH APPLICATION TO ARRAYS OF SENSORS AND FLEXIBLE STRUCTURES**

E. EMRE (Texas Tech University, Lubbock) IN: 1989 American Control Conference, 8th, Pittsburgh, PA, June 21-23, 1989, Proceedings, Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 1220-1225. Research supported by Texas Instruments, Inc. and Texas Advanced Technology Program. refs

(Contract AF-AFOSR-88-0078)

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An extended and unifying system identification technique is presented for a class of systems that includes all the main signal models that arise in the harmonic decomposition problem. This technique unifies and extends the previously developed system identification techniques which are improvements on the Pisarenko (MUSIC, dually) harmonic decomposition as they arise in arrays of sensors. This technique can be utilized to determine the dominant modes of vibration of flexible structures as well. An analogy is established between arrays of sensors receiving target signal returns after delays in the vibrations occurring in flexible structures. I.E.

AB-54032\* National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

**RAPID ROTATIONAL/TRANSLATIONAL MANEUVERING EXPERIMENTS OF A FLEXIBLE STEEL BEAM**

JER-NAN JUANG (NASA, Langley Research Center, Hampton, VA), LI-FARN YANG, JEN-KUANG HUANAG (Old Dominion University, Norfolk, VA), and RICHARD MACAULEY (Wyle Laboratories, Hampton, VA) IN: 1989 American Control Conference, 8th, Pittsburgh, PA, June 21-23, 1989, Proceedings, Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 1403-1408. refs

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Future space manipulators may need translational base motion to expand the access region of a manipulator. An experiment was conducted to demonstrate slewing of flexible structures with coupled rotational and translational axes while simultaneously suppressing vibrational motion during the maneuver. In the experiment, a flexible steel beam carried by a translational cart was maneuvered by an active controller to perform position-control tasks. Experimental results are presented to show how the flexibility of the steel beam influences the multi-input multi-output feedback controller. I.E.

**AB9-54080\*** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

#### FREQUENCY DOMAIN IDENTIFICATION EXPERIMENT ON A LARGE FLEXIBLE STRUCTURE

D. S. BAYARD, F. Y. HADAEIGH, Y. YAM, R. E. SCHEID, E. METTLER, and M. H. MILMAN (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: 1989 American Control Conference, 8th, Pittsburgh, PA, June 21-23, 1989, Proceedings, Volume 3, New York, Institute of Electrical and Electronics Engineers, 1989, p. 2532-2542. refs

Copyright

Recent experiences in the field of flexible structure control in space have indicated a need for on-orbit system identification to support robust control redesign to avoid in-flight instabilities and maintain high spacecraft performance. The authors highlight an automated frequency domain system identification methodology recently developed to fill this need. The methodology supports (1) the estimation of system quantities useful for robust control analysis and design, (2) experiment design tailored to performing system identification in a typically constrained on-orbit environment, and (3) the automation of operations to reduce human-in-the-loop requirements. A basic overview of the methodology is presented first, followed by an experimental verification of the approach performed on the JPL/AFAL testbed facility. I.E.

**AB9-54086#**

#### VIBRATION TESTING OF FLEXIBLE DUCT ASSEMBLIES

ARTHUR EDELSTEIN and RAY DEWINTER IN: Aerospace Testing Seminar, 11th, Manhattan Beach, CA, Oct. 11-13, 1988, Proceedings, Mount Prospect, IL, Institute of Environmental Sciences, 1988, p. 253-265.

This paper concerns vibration testing of a variety of flexible duct assemblies, ranging in size from two-inch diameter to 17-inch diameter. The primary focus is to look at two series of test programs to show how the lessons learned during these programs can be applied to future programs such as the space station. The paper is divided into three sections: the first concerning a series of vibration tests performed on 12-to-17-inch-diameter Shuttle cryogenic duct assemblies, the second concerning high-level vibration tests performed within the past year on some smaller (two-to-four-inch) Titan duct assemblies, and the third section acting as a summary/conclusion, showing how the test requirements and test methods progressed between the two programs and how this progression may affect similar programs in the future. Specific test requirements, sample test data, and relevant equipment schematics are included as necessary to supplement the text.

Author

**AB9-54785**

#### EIGENPROPERTIES OF LARGE-SCALE STRUCTURES BY FINITE ELEMENT PARTITIONING AND HOMOTOPY CONTINUATION

YAN ZHANG and RONALD S. HARICHANDRAN (Michigan State University, East Lansing) International Journal for Numerical Methods in Engineering (ISSN 0029-5981), vol. 28, Sept. 1989, p. 2113-2122. refs

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Finite element partitioning (or substructuring) is employed to estimate the eigenproperties of large-scale structural systems. A homotopy equation is constructed and its solutions are characterized by a number of curves which connect the eigenvalues of the partitions with those of the complete system.

A step-by-step tracing procedure is developed to follow these curves. At each step, prediction and correction are performed. The Rayleigh-Ritz procedure and the conjugate gradient method are used as predictor and corrector, respectively. Compared with the sole use of either the Rayleigh-Ritz or gradient methods, the proposed method is more reliable and more efficient for large-scale problems. Numerical implementation is well suited for supercomputers. Author

**N99-20152\*#** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

#### MODELING AND CONTROL OF FLEXIBLE STRUCTURES

J. S. GIBSON and D. L. MINGORI (California Univ., Los Angeles) 15 Dec. 1988 140 p  
(Contract NAS7-818)  
(NASA-CR-184862; JPL-PUBL-88-40; NAS 1.26:184862) Avail: NTIS HC A07/MF A01 CSCL 22A

This monograph presents integrated modeling and controller design methods for flexible structures. The controllers, or compensators, developed are optimal in the linear-quadratic-Gaussian sense. The performance objectives, sensor and actuator locations and external disturbances influence both the construction of the model and the design of the finite dimensional compensator. The modeling and controller design procedures are carried out in parallel to ensure compatibility of these two aspects of the design problem. Model reduction techniques are introduced to keep both the model order and the controller order as small as possible. A linear distributed, or infinite dimensional, model is the theoretical basis for most of the text, but finite dimensional models arising from both lumped-mass and finite element approximations also play an important role. A central purpose of the approach here is to approximate an optimal infinite dimensional controller with an implementable finite dimensional compensator. Both convergence theory and numerical approximation methods are given. Simple examples are used to illustrate the theory. Author

**N99-20186#** Dynamic Engineering, Inc., Haverlee (Belgium).

#### ERROR LOCALIZATION AND UPDATING OF SPACECRAFT STRUCTURES MATHEMATICAL MODELS Final Report

E. DASCOTTE Paris, France ESA Jun. 1988 173 p  
(Contract ESTEC-7512/87-NL-P4)  
(ESA-CR(P)-2697; ETN-89-93938) Avail: NTIS HC A06/MF A01

A procedure for updating finite element models for structural analysis was evaluated by means of a clamped porch, a tuning fork, an elastic clamped beam, and a spacecraft structure. Bayesian parameter estimation yields better error localization than the pseudo-inverse technique, although in general, this results in a slower iteration speed. Updated models can be used with more confidence when coupled with other structures or when a static analysis is performed. A higher number of eigenmodes included in the updating procedure yields better results for error localization. If the number of equations equals or is larger than the number of parameters, errors can be exactly identified. Measurement errors on the eigenfrequency can have an important influence on the parameter estimations. Amplification and reduction factors, as well as weighting coefficients prove to be valuable for optimizing convergence characteristics. ESA

**N99-21840\*#** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

#### OPTICAL FIBER SENSORS AND SIGNAL PROCESSING FOR INTELLIGENT STRUCTURE MONITORING Semiannual Report

ROBERT ROGOWSKI, R. O. CLAUS, D. K. LINDNER, DANIEL THOMAS, and DAVE COX Dec. 1988 50 p Prepared in cooperation with Virginia Polytechnic Inst. and State Univ., Blacksburg  
(Contract NAG1-895)  
(NASA-CR-184841; NAS 1.26:184841) Avail: NTIS HC A03/MF A01 CSCL 20/6

The analytic and experimental performance of optical fiber sensors for the control of vibration of large aerospace and other structures are investigated. In particular, model domain optical fiber

sensor systems, are being studied due to their apparent potential as distributed, low mass sensors of vibration over appropriate ranges of both low frequency and low amplitude displacements. Progress during the past three months is outlined. Progress since September is divided into work in the areas of experimental hardware development, analytical analysis, control design and sensor development. During the next six months, tests of a prototype closed-loop control system for a beam are planned which will demonstrate the solution of several optical fiber instrumentation device problems, the performance of the control system theory which incorporates the model of the modal domain sensor, and the potential for distributed control which this sensor approach offers. Author

**N89-21778** Purdue Univ., West Lafayette, IN.  
**DYNAMICS AND CONTROL OF TRUSS STRUCTURES WITH  
 EXTENDING MEMBERS** Ph.D. Thesis

RONG TYAI WANG 1988 137 p  
 Avail: Univ. Microfilms Order No. DA8900749

The effectiveness of using extendable truss members to tailor the vibrational characteristics of large truss structures is investigated. In contrast to the conventional control of structures using actuators mounted externally on the structure, the use of extendable truss members allows one to vary the control force internally, and, thus, achieve a change in natural frequencies and damping factors. If the actuator in the extendable member reacts to the member force instantaneously, then a negative gain will give rise to a stiffening effect and damping effect is also magnified. Explicit relations between the apparent structural stiffness and damping factor are derived in this study. If there is a delayed response in the actuator, then the gain must be chosen positive in order to achieve dynamic stability of the system. Further, the value of the gain must be less than unity. It is found that delay-time can be used most effectively to provide significant damping effect. Power transmission through a cell with extendable members is also studied. The power loss of a wave passing through this cell is found to depend highly on the modes of wave and on its wavelength. The potential use of the extendable members in the cells at the boundary of the structure is also investigated. For a wave with given frequency, it is possible to design the internal control force to completely absorb the energy of the incident wave. For large truss structures consisting of repeating identical cells, the dynamic characteristics can be found from the typical cell. A simple procedure is presented to derive natural frequencies of large structures from a single cell characteristics. Dissert. Abstr.

**N89-21822** Maryland Univ., College Park.  
**MODELING AND CONTROL OF MIXED AND FLEXIBLE  
 STRUCTURES** Ph.D. Thesis

THOMAS ALFRED POSBERGH 1988 186 p  
 Avail: Univ. Microfilms Order No. DA8827109

Crucial to successful controller design for flexible spacecraft is accurate modeling of the underlying distributed parameter system. Current techniques frequently fail to capture the nonlinear features of the dynamic behavior of flexible spacecraft. From a practical point of view a closely related issue is the fidelity of approximations in preserving the essential characteristics of the underlying distributed parameter system. Distributed parameter models and rigorous approximations of the same are the basis for control system analysis and design. Specifically, the generic case of a rigid spacecraft to which a flexible appendage was attached was examined. The flexible appendage was modeled using geometrically exact rod theory. Equilibria for stationary and rotating configurations were computed and used as the basis of a subsequent linearization which preserves the Hamiltonian structure of the underlying system. These linearized models were the basis of the construction of the corresponding transfer functions. The associated transfer functions relate tip position and acceleration of the appendage to rigid body torques. In addition, stability of these equilibria was investigated using the Energy-Casimir method. Using the transfer functions of the linearized model, modern frequency domain methods can be employed to do compensator design. In addition, a rigid n-body chain is a natural approximation

to a limiting case of the geometrically exact beam. Such an approximation provides the basis for finite dimensional compensator design for the infinite dimensional system. The design, implementation, and actual performance of such a compensator for an existing laboratory test fixture is discussed. Dissert. Abstr.

**N89-21825#** Lawrence Livermore National Lab., CA.  
**DISTRIBUTED FINITE ELEMENT MODELING AND  
 TECHNIQUES FOR SPACE STRUCTURES**

K. D. YOUNG 29 Jan. 1989 11 p Presented at the 3rd Annual NASA/ODD Control Structures Integration Conference, San Diego, CA, 29 Jan. - 2 Feb. 1989  
 (Contract W-7405-ENG-48)  
 (DE89-007226; UCRL-100410; CONF-890184-1) Avail: NTIS HC A03/MF A01

This paper describes an unconventional framework for the design of decentralized controllers for large flexible structures. In contrast to conventional control system design practice which begins with a model of the open loop plant, the controlled plant is assembled from controlled components in which the modeling phase and the control design phase are integrated at the component level. The developed framework is called Controlled Component Synthesis (CCS) to reflect that it is motivated by the well developed Component Mode Synthesis (CMS) methods which have been demonstrated to be effective for solving large complex structural analysis problems for almost three decades. The design philosophy behind CCS is also closely related to that of the Subsystem Decomposition Approach in decentralized control.

DOE

**N89-21831#** Naval Postgraduate School, Monterey, CA.  
**UTILIZATION OF A KALMAN OBSERVER WITH LARGE  
 SPACE STRUCTURES** M.S. Thesis

BRUCE M. JACKSON Dec. 1988 84 p  
 (AD-A205138) Avail: NTIS HC A05/MF A01 CSCL 22/1

Control of the motions and vibrations of large space structures requires the knowledge of state values that may not be available due either to inability to measure the states or, the high cost of the sensors to measure the required states. One solution is the use of an observer to estimate the states from limited sensor input. The physical characteristics of large space structures and the environment they operate in will cause large amounts of noise in the measurements. The obvious observer for such an environment is the Kalman Filter which is specifically designed to produce optimal estimates in a noisy environment. A straightforward application of the Kalman Filter will be examined utilizing a steady state Kalman gain matrix. The observer performance will be examined in both matched filter/plant and reduced order filter configurations. GRA

**N89-22440#** Sandia National Labs., Albuquerque, NM.  
**Experimental Mechanics Dept.**

**MEASUREMENT OF TIME-DEPENDENT EXTERNAL MOMENTS  
 AND FORCES BY THE SUM OF WEIGHTED ACCELERATIONS  
 TECHNIQUE**

T. G. PRIDDY, D. L. GREGORY, and R. G. COLEMAN Jan. 1989 44 p  
 (Contract DE-AC04-78DP-00789)  
 (DE89-007701; SAND-88-3081) Avail: NTIS HC A03/MF A01

Force identification using a sum of weighted accelerations technique (SWAT) is developed for measurement of externally applied force and moment which dynamically excite a structural system. Mode shape coefficients, from a free-body modal characterization, are used to determine two sets of weighting factors which, when used in the SWAT, eliminate the free-body vibrational response. One set of weighting factors, having the units of mass, are used in the SWAT measurement of the resultant force vector. The second set of weighting factors, having the units of first-moment-of-mass, are calculated to measure the moment acting at the center of mass of the external force with a similar sum of weighted accelerations. The theory for determining the force and moment vectors is developed in this paper. We illustrate



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the technique through the analysis of a simple beam and a rectangular plate. We then demonstrate the analytical predictions with the laboratory testing of softly suspended structures. DOE

**N89-22945#** DYNACS Engineering Co., Inc., Clearwater, FL.  
**A NASTRAN/TREETOPS SOLUTION TO A FLEXIBLE,  
MULTI-BODY DYNAMICS AND CONTROLS PROBLEM ON A  
UNIX WORKSTATION**

JAVIER E. BENAVENTE and NORRIS R. LUCE *In Computer Software Management and Information Center Seventeenth NASTRAN (R) Users' Colloquium* p 133-158 Mar. 1989  
Avail: NTIS HC A17/MF A03; also available from COSMIC, Athens, GA 30602 CSCL 20/11

Demands for nonlinear time history simulations of large, flexible multibody dynamic systems has created a need for efficient interfaces between finite-element modeling programs and time-history simulations. One such interface, TREETOPS, an interface between NASTRAN and TREETOPS, a nonlinear dynamics and controls time history simulation for multibody structures, is presented and demonstrated via example using the proposed Space Station Mobile Remote Manipulator System (MRMS). The ability to run all three programs (NASTRAN, TREETOPS and TREETOPS), in addition to other programs used for controller design and model reduction (such as DMATLAB and TREESEL, both described), under a UNIX Workstation environment demonstrates the flexibility engineers now have in designing, developing and testing control systems for dynamically complex systems. Author

**N89-23230#** Sandia National Labs., Albuquerque, NM. Applied Mechanics Div.

**NONLINEAR FINITE ELEMENT SIMULATION OF THE LARGE  
ANGLE MOTION OF FLEXIBLE BODIES**

LEE D. PETERSON 1989 32 p Presented at the 30th Structures, Structural Dynamics and Materials Conference, Mobile, AL, 3 Apr. 1989  
(Contract DE-AC04-76DP-00789)  
(DE89-006505; SAND-88-2366C; CONF-8904112-2; AIAA-89-1201) Avail: NTIS HC A03/MF A01

Finite element simulations of the geometrically nonlinear, large angle motion of flexible bodies are presented and discussed. The simulations use ABAQUS, a commercially available nonlinear, large strain-displacement structural finite element program. To evaluate the capabilities of ABAQUS, simulation results for three examples are presented: a large angle maneuver of a cantilevered beam, the nutation of a rotating free-free beam observed from a rotating frame, and the spin-up of a cantilevered beam from rest. The spin-up problem is a standard test case which tests for false divergence of the beam above a critical spin rate. In these simple examples, ABAQUS successfully simulates the large rotational motion, correctly capturing the geometrically nonlinear effects. The success of these simple examples indicates that ABAQUS, or similar nonlinear finite element programs, could be used to simulate the large angle rotation of arbitrary structures when a high fidelity truth model is desired. DOE

**N89-23508#** Aerospatiale Aquitaine, Saint-Medard en Jalles (France). Lab. des Matériaux.

**BREAK DIMENSIONING OF SPACE STRUCTURAL  
ASSEMBLIES AND ITS EXPERIMENTAL VALIDATION  
[DIMENSIONNEMENT A RUPTURE D'ASSEMBLAGES  
STRUCTURAUX SPATIAUX ET VALIDATION  
EXPERIMENTALE]**

JEAN-PIERRE MAIGRET and MICHEL MARTIN Paris, France 1988 4 p In FRENCH Presented at the 2nd International ADHECOM Congress, Mar. 1989  
(REPT-882-430-109; ETN-89-94490) Avail: NTIS HC A01/MF A01

The thermomechanical behavior of adhesive bonded metal to composite assemblies and the characterization of the adhesive systems are studied. Computerized simulation procedures and computing routines are developed using the finite difference

method. Thermomechanical complex loadings are considered. The solutions are based on the Goland and Reissner model. The first results are compared to those of the finite element method. ESA

**N89-23530#** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

**STRUCTURAL MATERIALS FOR SPACE APPLICATIONS**

DARREL R. TENNEY *In its NASA/SDIO Space Environmental Effects on Materials Workshop, Part 1* p 25-52 May 1989  
Avail: NTIS HC A16/MF A02 CSCL 22/2

The long-term performance of structural materials in the space environment is a key research activity within NASA. The primary concerns for materials in low Earth orbit (LEO) are atomic oxygen erosion and space debris impact. Atomic oxygen studies have included both laboratory exposures in atomic oxygen facilities and flight exposures using the Shuttle. Characterization of atomic oxygen interaction with materials has included surface recession rates, residual mechanical properties, optical property measurements, and surface analyses to establish chemical changes. The Long Duration Exposure Facility (LDEF) is scheduled to be retrieved in 1989 and is expected to provide a wealth of data on atomic oxygen erosion in space. Hypervelocity impact studies have been conducted to establish damage mechanisms and changes in mechanical properties. Samples from LDEF will be analyzed to determine the severity of space debris impact on coatings, films, and composites. Spacecraft placed in geosynchronous Earth orbit (GEO) will be subjected to high doses of ionizing radiation which for long term exposures will exceed the damage threshold of many polymeric materials. Radiation interaction with polymers can result in chain scission and/or cross-linking. The formation of low molecular weight products in the epoxy plasticize the matrix at elevated temperatures and embrittle the matrix at low temperatures. This affects both the matrix-dominated mechanical properties and the dimensional stability of the composite. Embrittlement of the matrix at low temperatures results in enhanced matrix microcracking during thermal cycling. Matrix microcracking changes the coefficient of thermal expansion (CTE) of composite laminates and produces permanent length changes. Residual stress calculations were performed to estimate the conditions necessary for microcrack development in unirradiated and irradiated composites. The effects of UV and electron exposure on the optical properties of transparent polymer films were also examined to establish the optimum chemical structure for good radiation resistance. Thoughts on approaches to establishing accelerated testing procedures are discussed. Author

**N89-23905#** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

**DOUBLE LEAD SPIRAL PLATEN PARALLEL JAW END  
EFFECTOR**

DAVID C. BEALS *In NASA, Marshall Space Flight Center, The 23rd Aerospace Mechanisms Symposium* p 195-206 Mar. 1989  
Avail: NTIS HC A15/MF A02 CSCL 22/2

The double lead spiral platen parallel jaw end effector is an extremely powerful, compact, and highly controllable end effector that represents a significant improvement in gripping force and efficiency over the LaRC Puma (LP) end effector. The spiral end effector is very simple in its design and has relatively few parts. The jaw openings are highly predictable and linear, making it an ideal candidate for remote control. The finger speed is within acceptable working limits and can be modified to meet the user needs; for instance, greater finger speed could be obtained by increasing the pitch of the spiral. The force relaxation is comparable to the other tested units. Optimization of the end effector design would involve a compromise of force and speed for a given application. Author

**N89-23924#** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

**LOCATING DAMAGED MEMBERS IN A TRUSS STRUCTURE  
USING MODAL TEST DATA: A DEMONSTRATION  
EXPERIMENT**

SUZANNE WEAVER SMITH (Virginia Polytechnic Inst. and State Univ., Blacksburg.) and PAUL E. MCGOWAN Apr. 1989 9 p  
Presented at the 30th Structures, Structural Dynamics and Materials Conference, Mobile, AL, 3-5 Apr. 1989  
(NASA-TM-101595; NAS 1.15:101595) Avail: NTIS HC A02/MF A01 CSCL 20/11

On-orbit assessment of large flexible space truss structures can be accomplished, in principle, with dynamic response information, structural identification methods, and model correlation techniques which produce an adjusted mathematical model. In a previously developed approach for damage location, an optimal update of the structure model is formed using the response data, then examined to locate damaged members. An experiment designed to demonstrate and verify the performance of the on-orbit assessment approach uses a laboratory scale model truss structure which exhibits characteristics expected for large space truss structures. Vibration experiments were performed to generate response data for the damaged truss. The damage location approach, analytical work performed in support of the vibration tests, the measured response of the test article, and some preliminary results are described. Author

N89-24634\*# Texas A&M Univ., College Station. Dept. of Aerospace Engineering.  
**A STUDY OF MATERIAL DAMPING IN LARGE SPACE STRUCTURES Final Technical Report**  
A. L. HIGHSMITH and D. H. ALLEN Apr. 1989 78 p  
(Contract NAG9-192)  
(NASA-CR-180076; NAS 1.26:180076; MM-5679-89-9) Avail: NTIS HC A05/MF A01 CSCL 20/11

A constitutive model was developed for predicting damping as a function of damage in continuous fiber reinforced laminated composites. The damage model is a continuum formulation, and uses internal state variables to quantify damage and its subsequent effect on material response. The model is sensitive to the stacking sequence of the laminate. Given appropriate baseline data from unidirectional material, and damping as a function of damage in one crossply laminate, damage can be predicted as a function of damage in other crossply laminates. Agreement between theory and experiment was quite good. A micromechanics model was also developed for examining the influence of damage on damping. This model explicitly includes crack surfaces. The model provides reasonable predictions of bending stiffness as a function of damage. Damping predictions are not in agreement with the experiment. This is thought to be a result of dissipation mechanisms such as friction, which are not presently included in the analysis. Author

N89-24644\*# Georgia Inst. of Tech., Atlanta.  
**SOME COMMENTS ON GLOBAL-LOCAL ANALYSES**  
SATYA N. ATLURI In NASA, Langley Research Center, Computational Methods for Structural Mechanics and Dynamics, Part 1 p 103-121 May 1989  
Avail: NTIS HC A15/MF A02 CSCL 20/11

The main theme concerns methods that may be classified as global (approximate) and local (exact). Some specific applications of these methods are found in: fracture and fatigue analysis of structures with 3-D surface flaws; large-deformation, post-buckling analysis of large space trusses and space frames, and their control; and stresses around holes in composite laminates. Author

N89-24660\*# National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.  
**RECENT DEVELOPMENTS IN DEPLOYMENT ANALYSIS SIMULATION USING A MULTI-BODY COMPUTER CODE**  
JERROLD M. HOUSNER In its Computational Methods for Structural Mechanics and Dynamics p 435-441 May 1989  
Avail: NTIS HC A12/MF A02 CSCL 09/2

Deployment is a candidate mode for construction of structural space systems components. By its very nature, deployment is a dynamic event, often involving large angle unfolding of flexible beam members. Validation of proposed designs and conceptual deployment mechanisms is enhanced through analysis. Analysis

may be used to determine member loads thus helping to establish deployment rates and deployment control requirements for a given concept. Furthermore, member flexibility, joint free-play, manufacturing tolerances, and imperfections can affect the reliability of deployment. Analyses which include these effects can aid in reducing risks associated with a particular concept. Ground tests which can play a similar role to that of analyses are difficult and expensive to perform. Suspension systems just for vibration ground tests of large space structures in a 1 g environment present many challenges. Suspension of a structure which spatially expands is even more challenging. Analysis validation through experimental confirmation on relatively small simple models would permit analytical extrapolation to larger more complex space structures. Author

N89-24661\*# National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.  
**DYNAMIC ANALYSIS OF SPACE STRUCTURES INCLUDING ELASTIC, MULTIBODY, AND CONTROL BEHAVIOR**  
LARRY PINSON and KETO SOOSAAR In its Computational Methods for Structural Mechanics and Dynamics p 443-454 May 1989  
Avail: NTIS HC A12/MF A02 CSCL 22/2

The problem is to develop analysis methods, modeling strategies, and simulation tools to predict with assurance the on-orbit performance and integrity of large complex space structures that cannot be verified on the ground. The problem must incorporate large reliable structural models, multi-body flexible dynamics, multi-tier controller interaction, environmental models including 1g and atmosphere, various on-board disturbances, and linkage to mission-level performance codes. All areas are in serious need of work, but the weakest link is multi-body flexible dynamics. Author

N89-24668\*# Massachusetts Inst. of Tech., Cambridge. Space Systems Lab.  
**NONLINEAR CHARACTERISTICS OF JOINTS AS ELEMENTS OF MULTI-BODY DYNAMIC SYSTEMS**  
EDWARD F. CRAWLEY In NASA, Langley Research Center, Computational Methods for Structural Mechanics and Dynamics p 543-569 May 1989  
Avail: NTIS HC A12/MF A02 CSCL 13/9

As the connecting elements in multi-body structures, joints play a pivotal role in the overall dynamic response of these systems. Obviously, the linear stiffness of the joint strongly influences the system frequencies, but the joints are also likely to be the dominant sources of damping and nonlinearities, especially in aircraft and space structures. The general characteristics of such joints will be discussed. Then the state of the art in nonlinear joint characterization techniques will be surveyed. Finally, the impact that joints have on the overall response of structures will be evaluated. Author

N89-24676\*# National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.  
**CHARACTERIZATION OF THE BENDING STIFFNESS OF LARGE SPACE STRUCTURE JOINTS**  
K. CHAUNCEY WU May 1989 18 p  
(NASA-TM-101565; NAS 1.15:101565) Avail: NTIS HC A03/MF A01 CSCL 20/11

A technique for estimating the bending stiffness of large space structure joints is developed and demonstrated for an erectable joint concept. Experimental load-deflection data from a three-point bending test was used as input to solve a closed-form expression for the joint bending stiffness which was derived from linear beam theory. Potential error sources in both the experimental and analytical procedures are identified and discussed. The bending stiffness of a mechanically preloaded erectable joint is studied at three applied moments and seven joint orientations. Using this technique, the joint bending stiffness was bounded between 6 and 17 percent of the bending stiffness of the graphite/epoxy strut member. Author

### 03 STRUCTURAL CONCEPTS

**N89-24677\*** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

#### DEVELOPMENT OF HIGHER-ORDER MODAL METHODS FOR TRANSIENT THERMAL AND STRUCTURAL ANALYSIS

CHARLES J. CAMARDA and RAPHAEL T. HAFTKA (Virginia Polytechnic Inst. and State Univ., Blacksburg.) Feb. 1989 39 p (NASA-TM-101548; NAS 1.15:101548) Avail: NTIS HC A03/MF A01 CSCL 20/11

A force-derivative method which produces higher-order modal solutions to transient problems is evaluated. These higher-order solutions converge to an accurate response using fewer degrees-of-freedom (eigenmodes) than lower-order methods such as the mode-displacement or mode-acceleration methods. Results are presented for non-proportionally damped structural problems as well as thermal problems modeled by finite elements. Author

**N89-24678\*** Astro Aerospace Corp., Carpinteria, CA.

#### INVESTIGATION OF STRUCTURAL BEHAVIOR OF CANDIDATE SPACE STATION STRUCTURE

JOHN M. HEDGEPEETH and RICHARD K. MILLER Jun. 1989 128 p (Contract NAS1-17536)

(NASA-CR-181746; NAS 1.26:181746; AAC-TN-1152) Avail: NTIS HC A07/MF A01 CSCL 20/11

Quantitative evaluations of the structural loads, stiffness and deflections of an example Space Station truss due to a variety of influences, including manufacturing tolerances, assembly operations, and operation loading are reported. The example truss is a dual-keel design composed of 5-meter-cube modules. The truss is 21 modules high and 9 modules wide, with a transverse beam 15 modules long. One problem of concern is the amount of mismatch which will be expected when the truss is being erected on orbit. Worst-case thermal loading results in less than 0.5 inch of mismatch. The stiffness of the interface is shown to be less than 100 pounds per inch. Thus, only moderate loads will be required to overcome the mismatch. The problem of manufacturing imperfections is analyzed by the Monte Carlo approach. Deformations and internal loads are obtained for ensembles of 100 example trusses. All analyses are performed on a personal computer. The necessary routines required to supplement commercially available programs are described. Author

**N89-25110\*** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

#### SPACE STATION FREEDOM STRUCTURAL CHARACTERIZATION EXPERIMENT (SCE) NODE CODE

ROBERT L. JENSEN May 1989 16 p (NASA-TM-101594; NAS 1.15:101594) Avail: NTIS HC A03/MF A01 CSCL 22/2

A method is described for naming the Space Station Freedom nodes and truss members that enhances the management, maintenance, and record keeping methods utilized by the space station. Author

**N89-25185\*** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

#### RESULTS OF AN INTEGRATED STRUCTURE/CONTROL LAW DESIGN SENSITIVITY ANALYSIS

MICHAEL G. GILBERT In *Recent Advances in Multidisciplinary Analysis and Optimization*, Part 2 p 727-745 Apr. 1989 Previously announced as N89-15111

Avail: NTIS HC A22/MF A03 CSCL 20/11

A design sensitivity analysis method for Linear Quadratic Cost, Gaussian (LQG) optimal control laws, which predicts change in the optimal control law due to changes in fixed problem parameters using analytical sensitivity equations is discussed. Numerical results of a design sensitivity analysis for a realistic aeroservoelastic aircraft example are presented. In this example, the sensitivity of the optimally controlled aircraft's response to various problem formulation and physical aircraft parameters is determined. These results are used to predict the aircraft's new optimally controlled response if the parameter was to have some other nominal value during the control law design process. The sensitivity results are

validated by recomputing the optimal control law for discrete variations in parameters, computing the new actual aircraft response, and comparing with the predicted response. These results show an improvement in sensitivity accuracy for integrated design purposes over methods which do not include changes in the optimal control law. Use of the analytical LQG sensitivity expressions is also shown to be more efficient than finite difference methods for the computation of the equivalent sensitivity information. Author

**N89-25226\*** California Univ., Berkeley. Coll. of Engineering. COMPUTATIONAL EXPERIMENTS IN THE OPTIMAL SLEWING OF FLEXIBLE STRUCTURES

T. E. BAKER and LUCIAN E. LUJAH POLAK In *NASA Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization*, Part 3 p 1427-1440 Apr. 1989

(Contract N00014-86-K-0295; NSF ECS-85-17362; AF-AFOSR-0116-86)

Avail: NTIS HC A22/MF A03 CSCL 20/11

Numerical experiments on the problem of moving a flexible beam are discussed. An optimal control problem is formulated and transcribed into a form which can be solved using semi-infinite optimization techniques. All experiments were carried out on a SUN 3 microcomputer. Author

**N89-25265** Michigan Univ., Ann Arbor.

#### TIME-OPTIMAL SLEWING MANEUVERS OF FLEXIBLE SPACECRAFT Ph.D. Thesis

GURKIRPAL SINGH 1988 162 p

Avail: Univ. Microfilms Order No. DA8907144

Two slewing problems are addressed: the time-optimal, rest-to-rest slewing problem (RTRSP) and the time-optimal spinup problem (SUP). The spacecraft is modeled as a finite-dimensional, linear, undamped, nongyroscopic system. The recognition and rigorous proof of symmetry of the optimal open-loop control histories about the mid-maneuver time is presented. Conditions for optimality are transformed, exploiting the symmetry property, into a set of nonlinear algebraic equations in one half of the control switching times, the maneuver time, and the costates at the mid-maneuver time. These equations are solved using a homotopy approach. The effect of residual modes on the open-loop system performance is quantified via the residual energy, the maximum post-maneuver attitude error (for the RTRSP), and the maximum post-maneuver attitude rate error (for the SUP). Upper bounds on these performance measures are given. For the special case of a single actuator located on the rigid central body, closed form expressions for these upper bounds are obtained for an infinite dimensional evaluation model. When only one control input is used to effect the slewings, the optimal control history is independent of the control input locations. The main assumption of this work is the absence of nonlinear rotational stiffening effects. This assumption might fail during slewings when large rotational rates are attained. We have proposed a simple condition which, when satisfied, justifies the omission of this nonlinearity from the equations of motion. This condition is validated by numerical simulations. The results, therefore, can be applied to many physical situations. Moreover, the results are applicable to all linear, elastic, nongyroscopic systems possessing one rigid body mode and a finite number of undamped elastic modes. Dissert. Abstr.

**N89-26266\*** Stanford Univ., CA. Dept. of Mechanical Engineering.

#### MATHEMATICAL MODELING AND NUMERICAL SIMULATION OF THE DYNAMICS OF FLEXIBLE STRUCTURES SUBJECT TO LARGE OVERALL MOTIONS Final Report, 31 Jul. 1988 - 30 Jul. 1988

J. C. SIMO 1989 19 p

(Contract AF-AFOSR-0292-86; AF PROJ. 2304)

(AD-A207004; AFOSR-89-0425TR) Avail: NTIS HC A03/MF A01 CSCL 20/11

A new modelling and computational task for the integrated design of flexible structures undergoing large overall motions has been developed and analyzed. This new approaches utilizes



geometrically exact structured models and have the advantage that these models can handle coupled rigid body-flexible appendage systems without resorting to the introduction of the so-called floating frames. GRA

**N89-26543\*** # Edinburgh Univ. (Scotland).

**CONTINGENT PLAN STRUCTURES FOR SPACECRAFT**

M. DRUMMOND, K. CURRIE, and A. TATE *In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 3 p 17-25 1 Jul. 1987*  
(Contract GR/D/58967; GR/E/05421)  
Avail: NTIS HC A18/MF A03 CSCL 22/2

Most current AI planners build partially ordered plan structures which delay decisions on action ordering. Such structures cannot easily represent contingent actions. A representation which can be presented. The representation has some other useful features: it provides a good account of the causal structure of a plan, can be used to describe disjunctive actions, and it offers a planner the opportunity of even less commitment than the classical partial order on actions. The use of this representation is demonstrated in an on-board spacecraft activity sequencing problem. Contingent plan execution in a spacecraft context highlights the requirements for a fully disjunctive representation, since communication delays often prohibit extensive ground-based accounting for remotely sensed information and replanning on execution failure. Author

**N89-26709#** Rockwell International Science Center, Thousand Oaks, CA.

**FIBER OPTIC SENSOR SYSTEM Final Report, 30 May 1986 - 1 Jun. 1988**

J. S. SCHOENWALD Mar. 1989 38 p  
(Contract F04611-86-C-0036; AF PROJ. 2864)  
(AD-A206636; SC5463.FRD; AFAL-TR-88-102) Avail: NTIS HC A03/MF A01 CSCL 20/6

The design, development, and performance of a microbend fiber optical domain reflectometry (OTDR) based distributed strains sensor are described. A test bed has been developed to evaluate and compare this system to conventional discrete strain gauge sensors. The test bed consists of an aluminum cantilever beam to which have been attached several pairs of strain gauges (for reference) and several microbend transducers. A single standard multi-mode optical fiber is threaded through the microbend transducers. The fiber is pulse illuminated by a commercial OTDR instrument. The microbend losses are detected as step changes in the return OTDR signal waveform. The transducers consist of small pairs of opposing sets of teeth, one set mounted on the flexible beam test bed, the other machined into a small, rigid cantilever bar mounted to produce scissor action as the beam flexes. The transducers are biased to produce a step loss with the beam in its neutral position. The direction of beam deformation is then determined by the increase or decrease of the step size. GRA

**N89-27215\*** # National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

**STABILITY AND DYNAMIC ANALYSIS OF A SLENDER COLUMN WITH CURVED LONGITUDINAL STIFFENERS**

MARK S. LAKE Aug. 1989 67 p  
(NASA-TM-101636; NAS 1.15:101636) Avail: NTIS HC A04/MF A01 CSCL 20/11

The results of a stability design study are presented for a slender column with curved longitudinal stiffeners for large space structure applications. Linear stability analyses are performed using a link-plate representation of the stiffeners to determine stiffener local buckling stresses. Results from a set of parametric analyses are used to determine an approximate explicit expression for stiffener local buckling in terms of its geometric parameters. This expression along with other equations governing column stability and mass are assembled into a determinate system describing minimum mass stiffened column design. An iterative solution is determined to solve this system and a computer program incorporating this routine is presented. Example design problems are presented which verify the solution accuracy and illustrate the

implementation of the solution routine. Also, observations are made which lead to a greatly simplified first iteration design equation relating the percent increase in column mass to the percent increase in column buckling load. From this, generalizations are drawn as to the mass savings offered by the stiffened column concept. Finally, the percent increase in fundamental column vibration frequency due to the addition of deployable stiffeners is studied. Author

**N89-27878\*** # Jet Propulsion Lab., California Inst. of Tech., Pasadena.

**STATE-OF-THE-ART FIBER OPTICS FOR SHORT DISTANCE FREQUENCY REFERENCE DISTRIBUTION**

G. F. LUTES and L. E. PRIMAS *In its The Telecommunications and Data Acquisition Report p 81-87 15 May 1989*  
Avail: NTIS HC A17/MF A03 CSCL 20/6

A number of recently developed fiber-optic components that hold the promise of unprecedented stability for passively stabilized frequency distribution links are characterized. These components include a fiber-optic transmitter, an optical isolator, and a new type of fiber-optic cable. A novel laser transmitter exhibits extremely low sensitivity to intensity and polarization changes of reflected light due to cable flexure. This virtually eliminates one of the shortcomings in previous laser transmitters. A high-isolation, low-loss optical isolator has been developed which also virtually eliminates laser sensitivity to changes in intensity and polarization of reflected light. A newly developed fiber has been tested. This fiber has a thermal coefficient of delay of less than 0.5 parts per million per deg C, nearly 20 times lower than the best coaxial hardline cable and 10 times lower than any previous fiber-optic cable. These components are highly suitable for distribution systems with short extent, such as within a Deep Space Communications Complex. Here, these new components are described and the test results presented. Author

**N89-28861#** Pacific Northwest Lab., Richland, WA.

**ACOUSTIC EMISSION TECHNOLOGY FOR SPACE APPLICATIONS**

M. A. FRIESEL, D. K. LEMON, J. R. SKORPIK, and P. H. HUTTON May 1989 13 p Presented at the 6th NASA Nondestructive Evaluation Workshop, Houston, TX, 23 May 1989  
(Contract DE-AC06-76RL-01830)  
(DE89-014449; PNL-SA-16952; CONF-8905178-2) Avail: NTIS HC A03/MF A01

Clearly the structural and functional integrity of space station components is a primary requirement. The combinations of advanced materials, new designs, and an unusual environment increase the need for inservice monitoring to help assure component integrity. Continuous monitoring of the components using Acoustic Emission (AE) methods can provide early indication of structural or functional distress, thus allowing time to plan remedial action. The term AE refers to energy impulses propagated from a growing crack in a solid material or from a leak in a pressurized pipe or tube. In addition to detecting a crack or leak, AE methods can provide information on the location of the defect and an estimate of crack growth rate and leak rate. DOE

**N89-28862#** CSA Engineering, Inc., Palo Alto, CA.

**OPTIMIZATION OF STRUCTURES WITH PASSIVE DAMPING AND ACTIVE CONTROLS Final Report, May - Nov. 1988**

WARREN C. GIBSON Feb. 1989 53 p  
(Contract F33615-88-C-5451)  
(AD-A208937; CSA-88-11-03; AFWAL-TR-88-4253) Avail: NTIS HC A04/MF A01 CSCL 13/13

Vibration suppression may be approached in three ways: by optimal distribution of structural mass, by viscoelastic damping treatments, and by active feedback control systems. Software design tools that address all three approaches are needed for SDI structures so that each approach can be exploited with minimal weight penalties. This report documents development in structural optimization under dynamic loads, both steady-state and transient. New methods for these problems are derived and demonstrated on small-scale structural models. The methods address

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minimization of structural mass subject to constraints on peak responses in either domain, together with frequency constraints and side constraints on member sizes. The methods are exercised with and without active control systems. GRA

**N89-28865#** Wisconsin Univ., Madison. Dept. of Mathematics. **MODELLING, INFORMATION, PROCESSING, AND CONTROL**. Final Scientific Report, 30 Sep. 1985 - 29 Sep. 1988

DAVID L. RUSSELL 15 Jan. 1989 118 p  
(Contract AF-AFOSR-0263-85; AF PROJ. 2304)  
(AD-A207810; AFOSR-89-0527TR) Avail: NTIS HC A06/MF A01  
CSCIL 20/11

Research was conducted in identification and control of distributed parameter systems, particularly damping mechanisms in distributed elastic systems, modeling of flexible structures, control of systems with nonlinear behavior and control of systems with solitary waves. A thorough analysis of damping mechanisms in elastic systems was carried out, including common classical forms of damping, which led to a new model of damping (spatial hysteresis) which correctly models observed asymptotic behavior in the frequency domain. More recent work focused on transfer function methods for infinite dimensional linear systems. Papers included some remarks on transfer function methods for infinite dimensional linear systems; spectral and asymptotic properties of linear elastic systems with internal damping; and frequency/period estimation and adaptive rejection of periodic disturbances. GRA

**N89-28869#** Cornell Univ., Ithaca, NY. Coll. of Engineering. **NONLINEAR DYNAMICS AND CONTROL OF FLEXIBLE STRUCTURES** Annual Report, 1 Oct. 1987 - 30 Sep. 1988  
FRANCIS C. MOON, PETER GERGELY, JAMES S. THORP, and JOHN F. ABEL 30 Mar. 1989 81 p  
(Contract F49620-87-C-0011)  
(AD-A208120; AFOSR-89-0595TR) Avail: NTIS HC A05/MF A01  
CSCIL 20/11

Chaotic vibrations were demonstrated in pinjointed truss structure and various factors involved, such as prestress (tension cables), member buckling, joint free-play and friction were investigated. Modeling techniques were developed through integration of finite and optimal controls, application of group theoretic concepts, and effective usage of computer graphics. GRA

**N89-29774#** National Aeronautics and Space Administration, Washington, DC.

#### **OVERVIEW OF THE NASA PROGRAM IN COMPUTATIONAL STRUCTURAL MECHANICS**

MURRAY HIRSCHBEIN In NASA, Langley Research Center, NASA Workshop on Computational Structural Mechanics 1987, Part 1 p 1-23 Feb. 1989  
Avail: NTIS HC A17/MF A03 CSCIL 20/11

In order to meet the anticipated needs in modeling and analysis of advanced aerospace structures, NASA has developed a program focused on computational structural mechanics. The objective of this program is to advance the state-of-the-art in computational analysis to make accurate analysis of very large and complex structural problems routine. This will be accomplished by emphasizing two key areas: (1) the development of advanced analytical methods, extending beyond traditional approaches and, (2) the exploitation of the newest and most powerful parallel/multiprocessor computers available. Computational testbeds will be developed to serve as technology integrators and to promote/accelerate methodology research and development. An additional, and highly desirable, effect of the Computational Structural Mechanics (CSM) program would be to influence the design of future hardware and software systems to reflect the needs of structural analysis. Author

### 04

#### **THERMAL CONTROL**

Includes descriptions of analytical techniques, passive and active thermal control techniques, external and internal thermal experiments and analyses and trade studies of thermal requirements.

**A89-36724#** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

#### **BIG SAVINGS FROM SMALL HOLES**

ALAN WHITE (NASA, Lewis Research Center, Cleveland, OH) Aerospace America (ISSN 0740-722X), vol. 27, May 1989, p. 32-35.

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The status and results to date of the NASA-Lewis/USAF Astronautics study of technology for large spacecraft heat-dissipation by means of liquid-droplet radiation (LDR) are discussed. The LDR concept uses a droplet generator to create billions of 200-micron droplets of a heatsink fluid which will cool through radiation into deep space as they fly toward a droplet collector. This exposure to the space environment entails the maintenance of vapor pressure as low as 10 to the -7th torr; the fluid must also be very stable chemically. While certain oils are good fluids for LDR use at low temperatures, higher-temperature heatsink fluids include Li, Sn, and Ga liquid metals. O.C.

**A89-38138**

#### **DEVELOPMENT OF THERMAL CONTROL MODULE FOR EARTH RESOURCES SATELLITE-1**

SUSUMU TODA, YUTAKA NAKAI, YOSHIO MASUDA (National Space Development Agency of Japan, Tokyo), MAKOTO KITADA, HIROMITSU MASUMOTO (Mitsubishi Electric Corp., Kamakura, Japan) et al. IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 839-844.

#### **Copyright**

This paper presents the design and the thermal balance test results of the thermal control module for the space panel of the Earth Resources Satellite-1. The thermal control system consists of four thermal louvers and twenty heat pipes embedded in an aluminum honeycomb panel. This thermal control system is considered to be suitable for the space panel in order to minimize a heater power and control their components' temperature. During thermal balance tests, all of the components' temperatures were controlled within their temperature limits. Author

**A89-38144**

#### **THERMAL STORAGE SYSTEM FOR SOLAR THERMODYNAMIC POWER GENERATOR OF SPACE FREEFLYER UNIT**

KOTARO TANAKA, YOSHIYUKI ABE, MASAYUKI KAMIMOTO, YOSHIO TAKAHASHI (Ministry of International Trade and Industry, Electrotechnical Laboratory, Tsukuba, Japan), and NOBUHIRO TANATSUGU (Institute of Space and Astronautical Science, Sagami-hara, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 891-896. refs

#### **Copyright**

A space thermodynamic power generation experiment is scheduled as a second mission of Space Flyer Unit (SFU). The present paper describes fundamental studies on latent thermal storage for SFU and other space energy applications. A major subject in this paper is the phase change behavior of containerized material which is one of the most critical problems not only for solar receiver but also in Solar Dynamic Power System itself. A solidification experiment under microgravity by using a trajectory flight sounding rocket of the Institute of Space and Astronautical



Science to be launched in 1989 is being prepared. The outline of the short-period experiment is described. Author

#### A89-38282

##### THERMAL CONTROL SYSTEM FOR JAPANESE EXPERIMENT MODULE

SUECHIKA MASUDA (National Space Development Agency of Japan, Tokyo), MINORI MIZUNO, and KEIZO NAKAO (Ishikawajima-Harima Heavy Industries, Co., Ltd., Tokyo, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1877-1882. Copyright

The baseline configuration of the Thermal Control System (TCS) of the Space Station (SS) Japanese Experiment Module (JEM) is defined by a preliminary design study. The preliminary design study was performed for two and a half years from 1985 to 1987 in order to define the functions of the JEM TCS, the functional/physical interfaces between the JEM TCS and the SS core TCS, the other systems and/or subsystems. This paper describes the baseline configuration as well as the significant trade-offs and analyses performed during the preliminary design phase. Author

#### A89-38357

##### OBSERVATION OF TWO-PHASE FLOW IN LOW GRAVITY ENVIRONMENT

YOSHINORI YOSHIMURA, SUECHIKA MASUDA (National Space Development Agency of Japan, Tokyo), MIKIO MORIOKA, KEIZO NAKAO, TOSHIHIRO SUGAWARA (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan) et al. IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 2387-2392. Copyright

A drop tower was used to study two-phase flow composed of liquid and gas in a low gravity environment. The effect of gravitational acceleration on the flow pattern is discussed. Two nondimensional correlations were derived to estimate the transition of the flow pattern in a horizontal two-phase flow. K.K.

#### A89-41316\*

##### Jet Propulsion Lab., California Inst. of Tech., Pasadena.

##### LONG-TERM PERFORMANCE OF THE PASSIVE THERMAL CONTROL SYSTEMS OF THE IRAS SPACECRAFT

P. V. MASON (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) (NASA, Space Cryogenics Workshop, Madison, WI, June 22, 23, 1987) Cryogenics (ISSN 0011-2275), vol. 26, Feb. 1988, p. 137-141. Copyright

Degradation of passive thermal control systems in space is a matter of serious concern and has been observed in many missions. The performance of the passive thermal control systems of the Infrared Astronomical Satellite (IRAS) over a period of three years is reported here. An exterior temperature of 200 K and a sunshade temperature of approximately 100 K were maintained over this period without significant degradation. The temperature of the telescope contained in the IRAS cryostat was also observed for two years after expenditure of the helium cryogen. It remained at 100 K with no degradation. Author

#### A89-43218#

##### TESTING OF A 30-KW PROTOTYPE SPACE STATION THERMAL BUS

R. BROWN, F. EDELSTEIN, and M. LIANDRIS (Grumman Corp., Grumman Space Systems Div., Bethpage, NY) AIAA, Thermophysics Conference, 24th, Buffalo, NY, June 12-14, 1989, 14 p. refs (AIAA PAPER 89-1702) Copyright

A prototype two-phase ammonia thermal bus has been built and tested for NASA Johnson Space Center for application on the Space Station. The system demonstrated its ability to operate in both separated flow and mixed two-phase flow modes.

Temperature control is maintained via liquid blockage of the condensers as controlled by a two-phase accumulator. In the separated flow mode, evaporator liquid supply valves controlled by ultrasonic liquid presence sensors maintain phase separation. Overall, the ambient tests were very successful, with the bus demonstrating a high degree of isothermality under variable loads (0.25 to 26.5 kW) and environments. Operation at both 70 and 35 F set points was achieved, with vapor line pressure drops of only a few tenths of a psi and pump power consumption of under 40 watts. Author

#### A89-43219#

##### COMPARATIVE EVALUATION OF TWO ATTACHMENT TECHNIQUES FOR SPACE STATION COLD PLATES

G. P. PETERSON, G. STARKS, and L. S. FLETCHER (Texas A & M University, College Station) AIAA, Thermophysics Conference, 24th, Buffalo, NY, June 12-14, 1989, 8 p. refs (AIAA PAPER 89-1703) Copyright

Two attachment techniques for mounting electronic equipment to Space Station cold plates were analyzed and compared. The characteristics evaluated include the temperature distributions at the electronic equipment/cold plate interface and the resulting thermal contact conductance. The two techniques evaluated were a 70 mm x 70 mm bolted attachment technique and an attachment scheme using an inflatable bladder. The results indicate that the bolted technique results in large variations in the local thermal contact conductance over the surface of the cold plate, while the pressurized bladder yields more uniform local contact conductance values. In addition, a uniform bladder pressure of 41.37 kPa (6 psi) resulted in a thermal contact conductance value approximately equal to that obtained for a bolt torque of 3.04 N-m (27 in-lbs), and higher uniform pressures resulted in substantially higher values of thermal contact conductance. Author

#### A89-45776

##### THERMAL EFFECTS ON LARGE SPACE STRUCTURES WITH FIXED ATTITUDE

R. B. MALLA (Connecticut, University, Storrs), W. A. NASH, and T. J. LARDNER (Massachusetts, University, Amherst) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 632-643. refs

(Contract AF-AFOSR-83-0025)

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Radiation thermal effects are studied simultaneously on the orbital motion and axial deformation of a very large axially flexible space structure executing planar pitch motion around the earth, whose attitude (orientation) is fixed at a particular direction. Effects of radiation heat sources available in the space environment, namely, direct solar, earth's albedo, and direct earth are studied on the space structure in elliptical orbits. Influences of the area-to-mass ratio of the structure on the thermal effects have been also investigated for such a structure in circular orbit. Radiation thermal effects are found to be significant in causing structural deformation of the large space structure. But, they are negligible on the structure's orbit. The area-to-mass ratio of the structure is observed to have remarkable influence on the thermal effects. Author

#### A89-45806

##### INDIRECT SOLAR LOADING OF WASTE HEAT RADIATORS

RONALD C. KIRKPATRICK, JAMES E. TABOR (Los Alamos National Laboratory, NM), ERICK L. LINDMAN (Mission Research Corp., Los Alamos, NM), and ALLEN J. COOPER (ARC, Monterey Park, CA) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 964-973. Copyright

Waste heat from space based power systems must ultimately be radiated away into space. The local topology around the radiators must be considered from two standpoints: the scattering

## 04 THERMAL CONTROL

of sunlight onto the surface of the radiator and the heat load that the radiator may put on nearby components of the system. A view factor code (SNAP) developed at Los Alamos allows the computation of the steady-state radiation environment for complex three-dimensional geometries. An example of the code's utility is given. Author

**AB9-51109**

### COMBINED RADIATION EFFECTS ON OPTICAL REFLECTANCE OF THERMAL CONTROL COATINGS

A. PAILLOUS, J. MARCO (ONERA, Centre d'Etudes et de Recherches de Toulouse, France), and F. LEVADOU (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 121-132. refs

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In the framework of an ESA contract, laboratory studies have been conducted on 22 thermal control coatings to determine the effect of a simulated space environment on their solar absorptance. The radiation exposure was accelerated in order to approximate the equivalent of seven years in geostationary earth orbit. Irradiations performed under vacuum included a combination of protons at 45 keV and 240 keV, electrons at 400 keV and ultraviolet radiation at 3.5 suns in intensity. The new test facility called SEMIRAMIS and specially designed for long term testing has been utilized for all irradiations and in situ measurements. The solar absorptance changes which have been measured are presented in terms of time elapsed in orbit for a number of paints, polymeric films, anodizations, second surface mirrors and solar cell covers. Author

**AB9-51133**

### HIGH TEMPERATURE RESISTANT COMPOSITE MATERIALS FOR SPACE APPLICATIONS

U. GLASER, J. EHRHARDT, and H. KRINGS (MAN Technologie GmbH, Munich, Federal Republic of Germany) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 539-548. Research supported by ESA.

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This paper presents the activities related to material investigations for high-temperature-resistant composites. On the basis of a set of given requirements, a preliminary selection of materials was performed via market analysis. The material properties at different temperatures after humidity exposure and thermal cycling were measured and discussed. Furthermore, panels typical of future space transporter systems were manufactured and tested. Author

**AB9-51134**

### NEW DEVELOPMENTS IN THERMO-OPTICAL COATINGS FOR SPACE VEHICLES

JEAN-CLAUDE GUILLAUMON (CNES, Toulouse, France) and FRANCOISE GUERARD (MAP, S.A., Pamiers, France) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 549-562.

Copyright

Various products with outgassing have been developed for satellites to provide efficient thermooptical control (conductive and nonconductive paints), equipotentiality, and high resistance to the space environment and to allow encapsulating, sticking, and varnishing. Low-outgassing encapsulating resins are used to produce electronic modules and to electrically insulate printed circuits, while low-outgassing conducting adhesives ensure electrical connections. Also considered are the development of lightning protection coatings (for launchers and aircraft) and transparent conducting coatings (for the Optical Surface Reflector and the Second Surface Mirror). R.R.

**AB9-51136**

### LOW ABSORPTANCE CMX OPTICAL SOLAR REFLECTORS

A. M. HEAD (Pilkington PE, Ltd., Space Technology, Bodelwyddan, Wales) and A. PAILLOUS (ONERA, Centre d'Etudes et de Recherches de Toulouse, France) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 571-579. Research supported by the British National Space Centre and ESA. refs

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Optical solar reflectors (OSRs) based on CMX ceria doped glass have been available for many years and have provided satisfactory performance on a number of European spacecraft as passive thermal control radiator devices. For the future, as satellites increase in their complexity and projected lifetimes, it is necessary to provide components with the optimum performance. The low absorptance OSR has therefore been developed and this offers an alpha/epsilon ratio which is half of that for the original OSR. The new product has been successfully demonstrated in typical test programs. This has included exposure to a simulated seven year duration in geostationary orbit on the SEMIRAMIS facility at CERT/DERTS. Author

**AB9-54087#**

### SPACE STATION ACTIVE THERMAL CONTROL SYSTEM TESTING

JOHN C. PIZZICHEMI (Boeing Aerospace, Seattle, WA) IN: Aerospace Testing Seminar, 11th, Manhattan Beach, CA, Oct. 11-13, 1988, Proceedings, Mount Prospect, IL, Institute of Environmental Sciences, 1988, p. 243-251. refs

The problems in providing thermal control for Space Station heat generating equipment, payload experiments, and crew personnel are described. The advantages of two-phase, evaporative-condensing heat transport systems for Space Station thermal control are presented and the issues associated with testing these systems are discussed. A design which eliminates many of the gravity-sensitivity problems in two-phase thermal control systems is presented, and a four-part test program for verifying/qualifying system operation on earth and in orbit are described. This test program consists of: (1) testing prototype components and performing life tests in the laboratory, (2) testing a sub-scale system in reduced gravity on the NASA KC-135, (3) testing a full-scale Space Station prototype system in laboratory ambient and thermal vacuum, and (4) testing a prototype system during an extended duration O-g flight in the Space Shuttle Orbiter cargo bay. Author

**N89-21023#** Lockheed Missiles and Space Co., Huntsville, AL. Engineering Center.

### CONJUGATING BINARY SYSTEMS FOR SPACECRAFT THERMAL CONTROL Final Report

PHILOMENA G. GROOMZKA, WILLIAM G. DEAN, LORI A. SISK, and ZAIN S. KARU Jan. 1989 112 p

(Contract NAS8-36199)

(NASA-CR-183608; NAS 1.26:183608; LMSC-HEC-TR-F226066)

Avail: NTIS HC A06/MF A01 CSCL 22/2

The materials search was directed to liquid pairs which can form hydrogen bonds of just the right strength, i.e., strong enough to give a high heat of mixing, but weak enough to enable phase change to occur. The cursory studies performed in the area of additive effects indicate that Conjugating Binary (CB) performance can probably be fine-tuned by this means. The Fluid Loop Test Systems (FLTS) tests of candidate CBs indicate that the systems Triethylamine (TEA)/water and propionaldehyde/water show close to the ideal, reversible behavior, at least initially. The Quick Screening Tests QSTs and FLTS tests, however, both suffer from rather severe static due either to inadequate stirring or temperature control. Thus it is not possible to adequately evaluate less than ideal CB performers. Less than ideal performers, it should be noted, may have features that make them better practical CBs than ideal performers. Improvement of the evaluation instrumentation is thus indicated. Author

**N89-21219#** Utah State Univ., Bedford, MA. Radiance Lab.  
**ADAPTING SCHOTTKY DIODE DETECTOR TECHNOLOGY TO A SPACE PLATFORM Final Report, Jul. 1986 - Jul. 1987**  
 JOSEPH KRISTL and RONALD HUPPI 10 Feb. 1988 281 p  
 (Contract F19628-86-K-0035)  
 (AD-A202825; AFGL-TR-87-0234) Avail: NTIS HC A13/MF A02  
 CSCL 17/5

Schottky barrier focal plane arrays have demonstrated superior performance in imagery and sensitivity in cameras deployed on the ground and on airborne platforms. This study determines the feasibility of placing a camera using one of these arrays in space in the space shuttle cargo bay or on the Shuttle Pallet Satellite. The basic operation and performance of platinum silicide Schottky barrier detectors is first discussed. Then a detailed analysis of all of the technical issues involved in constructing a space based Schottky camera are examined at length. Optical performance, cryogenic cooling, image compensation, data recording, system control, host platform restraints, and relevant MIL-SPECs are covered. A preliminary design that meets all of the design criteria is then described. It is concluded that this application is feasible and would be an extremely valuable research tool to investigate infrared properties of objects in space. GRA

**N89-21639#** Pacific Northwest Lab., Richland, WA.  
**THERMAL AND DYNAMIC ANALYSIS OF THE RING (RADIATIVELY-COOLED, INERTIALLY-DRIVEN NUCLEAR GENERATOR) POWER SYSTEM RADIATOR**  
 WALTER J. APLEY and ALBERT L. BABB (Washington Univ., Seattle) Jan. 1989 5 p Presented at the 6th Symposium on Space Nuclear Power Systems, Albuquerque, NM, 9 Jan. 1989  
 (Contract DE-AC06-76RL-01830)  
 (DE89-007236; PNL-SA-15971; CONF-890103-8) Avail: NTIS HC A01/MF A01

The nuclear option for a space-based power system appears most suitable for missions that require long-term, sustained operation at power levels above 100 kWe. Systems currently available operate at relatively low thermal efficiencies (6 to 10 percent). Thus, a 100 kWe system must discharge nearly 2 MWh of waste heat through the comparatively inefficient process of radiative cooling. The impact of the resultant radiator assembly size on overall power system weight is significant, and has led to proposals for radiators with potentially higher efficiencies. Examples include the liquid droplet radiator, fabric radiator, bubble membrane radiator, rotating film radiator, and dust radiator. DOE

**N89-22080#** Pacific Northwest Lab., Richland, WA. Energy Science Dept.  
**CONSTRUCTION AND TESTING OF ADVANCED CERAMIC FABRIC RADIATOR COMPONENTS**  
 ZENEN I. ANTONIAK and BRENT J. WEBB Jan. 1989 16 p  
 Presented at the 6th Symposium on Space Nuclear Power Systems, Albuquerque, NM, 9-12 Jan. 1989 Sponsored in part by AF  
 (Contract DE-AC06-76RL-01830)  
 (DE89-007239; PNL-SA-16305; CONF-890103-7) Avail: NTIS HC A03/MF A01

For a number of years, we have been studying the application of advanced ceramic fabric materials to spacecraft heat rejection systems. Our studies indicated that significant mass and launch volume savings could be realized through such application, but concrete evidence to support this contention was lacking. Recently, we have performed tests that support our claims. Test results demonstrate that thin (about 130 micrometers) fabric tubes lined with metal foil can sustain pressures to 3 MPa. Even more intriguing are the results of heat transfer measurements. Although several of the ceramic fabrics exhibit promising optical properties, these would require considerable improvement if transmission of radiant energy from the metal foil through the fabrics were to be the chief heat rejection mechanism. Instead, we have found that a complex combination of conduction and radiation-absorption-reradiation mechanisms, which are poorly understood yet, achieves an effective emittance of about 0.7. That is, a ceramic fabric material such as aluminoborosilicate, which is

normally considered a thermal insulator, acts as a moderate-emittance coating on the metal foil. DOE

**N89-22642#** Universidad Politecnica de Madrid (Spain). Lab. de Aerodinamica.  
**SPACECRAFT THERMAL CONTROL DESIGN DATA HANDBOOK Final Report**  
 I. DARIVA, D. RIVAS, and J. MESEGUER Paris, France ESA  
 Dec. 1987 5 p  
 (Contract ESTEC-6115/84/NL/MA(SC))  
 (LAMF-8712; ESA-CR(P)-2712; ETN-89-94242) Avail: NTIS HC A01/MF A01

Updates to certain pages of the ESA spacecraft thermal control design data handbook are indicated. ESA

**N89-23550\*#** Aerospace Corp., El Segundo, CA. Thermal Control Dept.  
**SPACE VEHICLE THERMAL TESTING: PRINCIPLES, PRACTICES AND EFFECTIVENESS**  
 DONALD F. GLUCK In NASA, Langley Research Center, NASA/SDIO Space Environmental Effects on Materials Workshop, Part 2 p 395-424 May 1989  
 Avail: NTIS HC A12/MF A02 CSCL 22/2

Component qualification and acceptance temperatures are derived from worst case thermal analyses and analytic uncertainty margin subject to certain specified temperature extremes. Temperature requirements are shown for equipment operation within specification and for survival and turn-on (need not operate within specification, but must not experience any degradation when returned to operational range). Temperature excursions for most equipment are seen to be 20 to 50 C above and below room temperature. Components without active electronics which are mounted outboard, such as solar arrays and antennas, are usually designed to withstand wider temperature excursions, particularly at the cold end. Batteries are tightly controlled at cold temperatures to increase life. Payload components such as extremely accurate clocks for precise navigation are controlled over a relatively narrow temperature range. Author

**N89-24440\*#** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.  
**FLIGHT EXPERIMENT OF THERMAL ENERGY STORAGE**  
 DAVID NAMKOONG 1989 9 p Presented at the 24th Intersociety Energy Conversion Engineering Conference, Washington, DC, 6-11 Aug. 1989; cosponsored by the IEEE, AIAA, ANS, ASME, SAE, ACS and AIChE  
 (NASA-TM-102081; E-4843; NAS 1.15:102081) Avail: NTIS HC A02/MF A01 CSCL 10/3

Thermal energy storage (TES) enables a solar dynamic system to deliver constant electric power through periods of sun and shade. Brayton and Stirling power systems under current considerations for missions in the near future require working fluid temperatures in the 1100 to 1300+ K range. TES materials that meet these requirements fall into the fluoride family of salts. These salts store energy as a heat of fusion, thereby transferring heat to the fluid at constant temperature during shade. The principal feature of fluorides that must be taken into account is the change in volume that occurs with melting and freezing. Salts shrink as they solidify, a change reaching 30 percent for some salts. The location of voids that form as result of the shrinkage is critical when the solar dynamic system reemerges into the sun. Hot spots can develop in the TES container or the container can become distorted if the melting salt cannot expand elsewhere. Analysis of the transient, two-phase phenomenon is being incorporated into a three-dimensional computer code. The code is capable of analysis under microgravity as well as 1 g. The objective of the flight program is to verify the predictions of the code, particularly of the void location and its effect on containment temperature. The four experimental packages comprising the program will be the first tests of melting and freezing conducted under microgravity. Each test package will be installed in a Getaway Special container to be carried by the shuttle. The package will be self-contained and independent of shuttle operations other than the initial opening of



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the container lid and the final closing of the lid. Upon the return of the test package from flight, the TES container will be radiographed and finally partitioned to examine the exact location and shape of the void. Visual inspection of the void and the temperature data during flight will constitute the bases for code verification. Author

**N89-25078\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.  
**INITIAL CHARACTERIZATION OF A MODULAR HEAT EXCHANGER WITH AN INTEGRAL HEAT PIPE**  
JEFFREY G. SCHREIBER 1989 8 p Presented at the 24th Intersociety Energy Conversion Engineering Conference, Washington, DC, 6-11 Aug. 1989; cosponsored by the IEEE, AIAA, ASME, SAE, ACS and AIChE  
(NASA-TM-102097; E-4659; NAS 1.15:102097) Avail: NTIS HC A02/MF A01 CSCL 05/1

As part of the Civil Space Technology Initiative (CSTI) Advanced Technology program, a conceptual design of the Stirling space engine (SSE) was generated. The overall goal of the CSTI high capacity power element is to develop the technology base needed to meet the long duration, high capacity power requirements for future NASA space missions. The free-piston Stirling engine (FPSE) was chosen as the growth option in the CSTI program. A major goal during the conceptual design of the SSE was to reduce the number of critical joints. One area of concern was the heat exchanger assemblies that typically have the majority of critical joints. The solution proposed in the SSE conceptual design used 40 modular heat exchangers. Each module has its own integral heat pipe to transport heat from the heat source to the engine. A demonstration of the modular concept was undertaken before committing to the detailed design of the SSE heat exchangers. An existing FPSE was modified as a test bed for modular heat exchanger evaluation. The engine incorporated three heat exchanger modules, each having a sodium filled heat pipe. The thermal loading of these modules was intended to be similar to the conditions projected for the SSE modules. The engine was assembled and tests are underway. The design and fabrication of the heat exchanger modules and the engine used for these tests were described. Evaluation of the individual heat pipes before installation in the engine is described. The initial test results with the modules in operation on the engine were presented. Future tests involving the engine were outlined. Author

**N89-25264\*** Science Applications International Corp., La Jolla, CA.  
**SURVIVABLE PULSE POWER SPACE RADIATOR Patent Application**  
JAMES MIMS, inventor (to DOE), DAVID BUDEN, inventor (to DOE), and KENNETH WILLIAMS, inventor (to DOE) 11 Mar. 1988 16 p  
(Contract DE-AC03-85SF-15928)  
(DE89-010120; PATENTS-US-A7167203; US-PATENT-APPL-SN-167203) Avail: NTIS HC A03/MF A01

An outer space vehicle thermal radiator system is described which must survive a long period of nonuse and then radiate large amounts of heat for a limited period of time. The radiator includes groups of radiator panels that are pivotally connected in tandem, so that they can be moved to deployed configuration wherein the panels lie largely coplanar, and to a stowed configuration wherein the panels lie in a stack to resist micrometeorite damage. The panels are mounted on a boom which separates a hot power source from a payload. While the panels are stowed, warm fluid passes through their arteries to keep them warm enough to maintain the coolant in a liquid state and avoid embrittlement of material. The panels can be stored in a largely cylindrical shell, with panels progressively further from the boom being of progressively shorter length. DOE

**N89-26038** Department of the Air Force, Washington, DC.  
**EXPANDABLE PULSE POWER SPACECRAFT RADIATOR Patent**  
EDWARD T. MAHEFKEY, inventor (to AF) 21 Mar. 1989 7 p

Filed 21 Oct. 1987

(AD-D014102; US-PATENT-4,813,476;  
US-PATENT-APPL-SN-110809; US-PATENT-CLASS-165-32)  
Avail: US Patent and Trademark Office CSCL 20/13

An expendable heat rejection system for radiating heat generated by a source of heat on a spacecraft or like vehicle is described. It is comprised of a fluid heat exchange medium in operative heat exchange contact with the source for absorbing heat by evaporation of the liquid phase of the medium, a thin flexible wall structure having an inlet and an outlet and defining a volume expandable and collapsible between preselected limits and defining an inner condensation surface and an outer heat radiating surface, a multiplicity of capillary grooves on the condensation surface for promoting condensation of vaporized medium and for facilitating flow of condensate along the condensation surface toward the outlet, and a pump for circulating the medium through the system. GRA

**N89-26182\*** University of Southern California, Los Angeles. Dept. of Aerospace Engineering.  
**LIQUID DROPLET GENERATION Final Report**  
E. P. MUNTZ, MELISSA ORME, TONY FARNHAM, G. PHAM VANDIEP, and P. HUERRE Jun. 1989 72 p  
(Contract NAS3-25066)  
(NASA-CR-182246; NAS 1.26:182246) Avail: NTIS HC A04/MF A01 CSCL 20/4

A pre-prototype segment of a droplet sheet generator for a liquid droplet radiator was designed, constructed and tested. The ability to achieve a uniform, non-diverging droplet sheet is limited by manufacturing tolerances on nozzle parallelism. For an array of 100, 100 micrometer diameter nozzles spaced 5 stream diameters apart, typical standard deviations in stream alignment were plus or minus 10 mrad. The drop to drop fractional speed variations of the drops in typical streams were similar and independent of position in the array. The absolute value of the speed dispersion depended on the amplitude of the disturbance applied to the stream. A second generation preliminary design of a 5200 stream segment of a droplet sheet generator was completed. The design is based on information developed during testing of the pre-prototype segment, along with the results of an acoustical analysis for the stagnation cavity pressure fluctuations used to break-up the streams into droplets. Author

**N89-27688\*** Aerospatiale, Cannes (France).  
**RADIATORS AND HEAT EXCHANGERS FOR SPACE APPLICATIONS**  
1988 16 p  
(REPT-882-440-115; ETN-89-94508) Avail: NTIS HC A03/MF A01

Radiator conceptual studies and heat exchangers for hybrid radiators are studied for space applications including Hermes, space stations, and orbiting platforms. Preliminary designs are analyzed and the choices made are described. ESA

**N89-27690\*** Aerospatiale, Cannes (France).  
**DEVELOPMENT OF HEAT EXCHANGERS FOR HYBRID RADIATORS**  
M. AMIDIEU and T. LAFON (Centre National d'Etudes Spatiales, Toulouse, France) in its Radiators and Heat Exchangers for Space Applications 8 p 1988  
Avail: NTIS HC A03/MF A01

Preliminary design concepts of heat exchangers for space station or orbiting platform hybrid radiators are discussed. The selection includes one dry contact exchanger in which the fluid circuit and the heat pipes contact each other through their outer shell and one wet contact exchanger, where one of the fluids comes into contact with the other element. After a comparative analysis taking in account performance, manufacturing and operational use, the dry contact exchanger is selected for future development. ESA



**NON-28216#** Entwicklungsring Nord, Bremen (Germany, F.R.).  
**SYSTEM ASPECTS OF COLUMBUS THERMAL CONTROL AND LIFE SUPPORT**

U. LAUX, B. BEHRENS, and R. LAWSON In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 15-23 Dec. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

Thermal Control and Life Support Systems of the Columbus flight configurations, the Attached Pressurized Module (APM), the Man Tended Free Flyer (MTFF) and the Polar Platform (PPF) are described. The overall APM and MTFF Environmental Control and Life Support System (ECLSS) is strongly affected by the interfaces to the International Space Station (ISS) and Hermes. It is proposed to centralize particular ECLSS functions of both the APM and MTFF for reasons of cost, mass, power, and complexity reduction and to operate the MTFF-ECLSS in a power saving mode during the free flying phase. Rejection of the APM generated heat is performed totally by the ISS, whereas the MTFF Thermal Control is fully autonomous in the free flying and Hermes servicing phase. The preferred MTFF orientation, which is driven by the very stringent microgravity requirement, is in conflict with the heat rejection capabilities of the TCS. ESA

**NON-28225#** Societe Anonyme Belge de Constructions Aeronautiques, Brussels.

**FEASIBILITY DEMONSTRATION MODEL OF A CAPILLARY PUMPING LOOP**

R. S. BHATTI, S. VANOOST, and C. J. SAVAGE (European Space Agency, European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 83-88 Dec. 1988

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The general objectives, the design concept, and the potential performances of the two-phase capillary pumping loop (CPL) as a heat transportation system are reviewed. Results obtained on the first breadboard CPL model are reported with comparison of predicted against tested performances. ESA

**NON-28227#** Minelectrotechprom, Moscow (USSR).

**NON-CONDENSIBLE GAS EFFECTS ON THE LOW-TEMPERATURE HEAT PIPE CHARACTERISTICS**

M. D. PARFENTIEV In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 97-101 Dec. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

Results of studies on noncondensable gas (NCG) distribution in condensation zones of low temperature heat pipes (LTHP) and estimates of its effect on distribution of both localized heat flows and localized heat-exchange coefficients as well as LTHP was temperature profile in condensation zone are described. Based on visual studies on vapor-gas mixture distribution in LTHP condensation zone, a NCG distribution model is proposed which considers distribution irregularities both in axial and radial directions. Using the accepted NCG distribution model as the base, the heat balance equation for a condenser wall component which considers variable thermal resistance of a NCG layer was obtained. ESA

**NON-28228#** Tokyo Univ., Sagamihara (Japan).

**MICRO-FLUID DYNAMICAL ANALYSIS OF EVAPORATING FLOWS IN HEAT PIPES**

K. OSHIMA and N. IZUTSU In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 103-108 Dec. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

Heat pipe systems utilizing phase changing heat transfer concepts are introduced, including micro heat pipes, a separate type heat pipe heat exchanger, and heat pipe turbines. Inside these heat pipes, contrary to the conventional thermosiphon, evaporation and condensation processes are heavily influenced by the surface tension effect. This effect is also dominant in heat pipes operating under microgravity in space. Similarity parameters concerning these phenomena are discussed. Laboratory experiments as well as numerical simulations of the flows relating to evaporative heat transfer were carried out. It is found that heat transfer by the evaporation process is decreased in such conditions. ESA

**NON-28229#** Minelectrotechprom, Moscow (USSR).

**EXPRESS-METHOD INVESTIGATION AND ITS APPLICATION FOR HEAT PIPE QUALITY CONTROL**

A. D. LOBANOV and A. A. PARENTIEVA In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 109-112 Dec. 1988

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Results of studies and application of a heat pipe quality control method applicable in the pipe series production (and introduced) into the heat pipe production process and on installing the heat pipes on cooled and controlled temperature instruments and equipment, with no pipes disconnected from these instruments, are described. A heat short time action (heat flux density ranges from units to tens of W/sq m and time interval, from units to tens of seconds) is applied upon an envelope of a working fluid filled and sealed heat pipe locally, that is on its small section (an area of 1 sq m) and the pipe envelope temperature increase at the heat short time action input section is registered during its effect time or a shorter period. It is possible to determine a heat pipe parameter controlled by making comparison with an increase in temperature premeasured at a reference device subjected to a similar effect. The method is used to check working fluid availability in a heat pipe, to test noncondensable gas absence (or presence of its given amount) therein. The method markedly accelerates heat pipe rejection and improve quality control reliability (one heat pipe requires only 30 sec for its testing). ESA

**NON-28245#** Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).

**THERMAL MODELLING OF THE EVA-SUITED ASTRONAUT**

L. SIMIONESCO and D. HORNET In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 227-232 Dec. 1988

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A computer thermal model which integrates the man-in-the-loop was developed in order to analyze the interactions between the human self-regulating thermal mechanisms and the behavior of the ELSS, water and gas heat transport loops. Because the human thermodynamic behavior is dependent on its own thermal status (metabolic activity and core temperature) and on its environment (gas constituents partial pressures and relevant temperatures) those variables had to be introduced into the conventional heat and mass transfer scheme. ESA

**NON-28247#** Dornier System G.m.b.H., Friedrichshafen (Germany, F.R.).

**ADVANCED MODULAR SOFTWARE DEVELOPMENT IN THERMAL ENGINEERING**

R. BISANZ and F. ZILLY In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 241-248 Dec. 1988

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A Concept for Simulation and Analysis of Space Systems (COSIMA) was developed utilizing advanced modular software

## 04 THERMAL CONTROL

engineering techniques and the software management system RSYST. Realizations in various disciplines and project applications demonstrated the advantages of this concept. The main components of COSIMA and its application to thermal radiation software development, and a materials data base are described. Help facilities are outlined. ESA

**N89-28254#** Aeritalia S.p.A., Turin (Italy).

### AN ALGORITHM FOR CALCULATING THERMODYNAMIC PROPERTIES OF SIMPLE FLUIDS SUITABLE FOR SPACE THERMAL CONTROL

C. ACTIS and N. NERVEGNA (Politecnico di Torino, Italy) In ESA, Third European Symposium Space Thermal Control and Life Support Systems p 289-295 Dec. 1988

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A method for calculating equilibrium thermodynamic properties of a simple fluid is proposed. Following the rigorous theory of statistical mechanics an equation of state that describes both the liquid and vapor state of a two parameter fluid is developed. The formulation is not purely analytic being based on an algorithm implemented in a FORTRAN package. At the modeling stage the real fluid behavior is portrayed via a quasi Lennard-Jones molecular interaction potential. The perturbation theory of Barker and Henderson is used while a variational minimization criterion leads to the selection of the hard-sphere particles diameter thus identifying the reference system. By so doing, the isotropic pair interaction is dictated by a hard sphere potential perturbed by an attractive term. Of significance is the fact that potential parameters are made dependent on both specific volume and temperature. The method was tested for argon due to its nonpolar characteristics and simple molecular structure. Argon is of interest in both cryogenics and dynamic energy conversion systems for space use, especially in connection with mixtures where molecular mass values can be adjusted to compromise rotating machinery vs heat transfer efficiencies. Results from this formulation are compared with other correlations as well as with experimental data at specific state points. ESA

**N89-28281#** GEC Power Engineering Ltd., Whetstone (England).

### ESATAN FHTS: A PIPED FLUID NETWORK CAPABILITY

J. R. TURNER, T. J. SWIFT, T. M. ANDREWS, and A. LEBRU (European Space Agency, European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 483-487 Dec. 1988

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The ESATAN thermal analysis package was extended to incorporate predictions of fluid pressure and mass flow rate in one-dimensional, piped fluid networks. This is in addition to the original capability of thermal analysis. The ESATAN Fluid Heat Transport System (FHTS) is capable of steady state or transient analyses, with single or two-phase fluid flow. Users are able to construct piped fluid systems from basic node and conductance data, and also incorporate predefined elements which are used to simulate hardware such as pumps and heat exchangers. Previous thermal model input decks are compatible with the new system. Analysis may be all-fluid, all-thermal, or both fluid and thermal simultaneously. ESA

**N89-28285#** Aerospatiale, Cannes (France).

### DEVELOPMENT OF HEAT EXCHANGERS FOR HYBRID RADIATORS

M. AMIDIEU and T. LAFON (Centre National d'Etudes Spatiales, Toulouse, France) In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 515-522 Dec. 1988

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A preliminary study yielded two basic concepts for a heat exchanger, namely: one dry contact exchanger in which the fluid circuit and the heat pipes contact each other through their outer shell; one wet contact exchanger, where one of the fluids comes into contact with the other element. From a comparative analysis of the two concepts, taking into account criteria of performance, manufacturing and operational use, the dry contact exchanger was selected for development. ESA

**N89-28286#** Martin Marietta Aerospace, Denver, CO. Astronautics Group.

### DEVELOPMENT OF A NOVEL HIGH-PERFORMANCE CONTACT HEAT EXCHANGER

W. H. MILLER and T. BUNA In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 523-528 Dec. 1988

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The development of a contact heat exchanger for space station type applications with the objective of providing on-orbit replaceability of damaged or degraded radiators is described. The device is to provide disconnect type thermal coupling between heat pipe radiators and the internal heat transport fluid loops of the thermal management system. The key issue to be resolved was to ensure precise mating between the contact surfaces, determined to be a necessary condition for ensuring the required high conductance. This was achieved by the use of precision manufacturing techniques and the use of a conical contact geometry. Analyses, test approach, and results are presented indicating a highly competitive thermal performance. ESA

**N89-28288#** Fokker B.V., Amsterdam (Netherlands). Space and Systems Div.

### A 1-KW CONDENSER FOR A TWO-PHASE HEAT REJECTION SYSTEM

H. VONLONKHUYZEN and N. H. PENNINGS In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 537-541 Dec. 1988 Sponsored by Dornier System GmbH, Friedrichshafen, Fed. Republic of Germany

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A breadboard model of a 1 kW spacecraft condenser unit was designed, manufactured, and tested. The condenser forms part of a 15 kW mechanically pumped two-phase flow (TPF) heat rejection system. A thermal-hydraulic analysis of such a heat rejection system shows that a parallel layout of radiator panels and condenser branches is preferred. The 1 kW condenser consists of two parallel branches. Each branch is made of an aluminum extrusion profile with 15 parallel channels and a porous plug. The condenser can be integrated in a two-sided radiating panel of 1.8 x 1.8 m sq. The test results of the condenser breadboard model show that the thermal-hydraulic behavior is a factor 1.5 to 2 better than the performance predicted by the Lockhart-Martinelli theory. For a 1 kW heatload the pressure drop over the condenser is 0.02 bar and the temperature drop from the TPF mixture to the outer surface of the condenser is 1.5 C. ESA

**N89-28289#** Tokyo Univ. (Japan).

### A VERY LOW REFLECTANCE DIFFUSE SURFACE FOR THERMAL DESIGN OF SPACECRAFT

A. OHNISHI, K. KANEKO, and T. HAYASHI In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 543-545 Dec. 1988

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A very low reflectance diffuse surface for thermal control coating of spacecraft is proposed. This method is based on electrostatic flocking of carbon fiber to a surface previously coated with adhesive

to fix the fiber vertically to the surface. The surface region surrounded by carbon fiber behaves microscopically as a lossy terminal for electromagnetic waves in visible and IR regions, and diffuse black surface with high stability would be attained. ESA

**N89-28290#** Ansaldo S.p.A., Genoa (Italy).

**A MAGNETICALLY-DRIVEN DROPLET RADIATOR CONCEPT**  
P. G. AVANZINI, S. VALENTINI, and G. TUNNETTI in ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 547-552 Dec. 1988  
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The liquid droplet radiator (LDR) is described. It features a solenoid magnet constraining a radiating surface of droplets in a toroidal configuration. An annular droplet generator surrounds the magnet. Two streams of ferromagnetic droplets are generated in opposite directions, driven by the magnetic field along curvilinear trajectories, collected inside the magnet, and recirculated to the generator after cooling in a heat exchanger interfacing heat rejection and thermal control loops. Advantages are expected in system compactness and reduction of coolant losses. A model is developed to predict the motion of a ferromagnetic droplet in a magnetic field, in order to investigate the feasibility of the concept. ESA

**N89-28295#** Erno Raumfahrttechnik G.m.b.H. Bremen (Germany, F.R.).

**THEORETICAL AND EXPERIMENTAL INVESTIGATIONS ON HEAT EXCHANGERS FOR COLUMBUS HYBRID RADIATORS**  
W.-D. EBELING and R. MEYER in ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 583-590 Dec. 1988  
Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

Parallel to the development of the Columbus system, ESA initiated a Preparatory Support Technology Programme (PSTP). In the frame of PSTP1, of a hybrid radiator Technical Demonstration Model (TDM) was developed. The thermo-hydraulic acceptance tests of the heat exchanger TDM show that the requirements concerning minimum heat transfer rate and maximum allowable pressure drop are met at the design point. The component tests on fin packages of different geometry show that the theoretical determination of thermohydraulic properties of offset strip fin packages using empirical correlations concerning the heat transfer rate is limited. Flow instabilities may cause a steep decrease in the convection coefficient within a limited Reynolds-number regime. Therefore, thermohydraulic component tests on selected fin geometries are required for the selection of a best suited fin configuration. This procedure which is applied for the development of the heat exchanger TDM is justified by the results of the component tests. ESA

**N89-28556#** National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, AL.

#### SPACECRAFT COMPONENT HEATER CONTROL SYSTEM

##### Patent Application

FREDERICK D. BACHTEL, inventor (to NASA) and JAMES W. OWEN, inventor (to NASA) 5 Jun. 1989 16 p  
(NASA-CASE-MFS-28327-1; NAS 1.71:MFS-28327-1;  
US-PATENT-APPL-SN-361200) Avail: NTIS HC A03/MF A01  
CSCI 22/2

A heater control circuit is disclosed as being constructed in a single integrated circuit, with the integrated circuit conveniently mounted proximate to a spacecraft component requiring temperature control. Redundant heater controllers control power applied to strip heaters disposed to provide heat to a component responsive to sensed temperature from temperature sensors. Signals from these sensors are digitized and compared with a dead band temperature and set point temperature stored in memory to generate an error signal if the sensed temperature is outside the parameter stored in the memory. This error signal is utilized

by a microprocessor to selectively instruct the heater controllers to apply power to the strip heaters. If necessary, the spacecraft central processor may access or interrogate the microprocessor in order to alter the set point temperature and dead band temperature range to obtain operational data relating to the operation of an integrated circuit for relaying to the ground control, or to switch off faulty components. NASA

## 05

### ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEMS

Includes description of analytical techniques and models, trade studies of technologies, subsystems, support strategies, and experiments for internal and external environmental control and protection, life support systems, human factors, life sciences and safety.

**A89-37673\*** Hawaii Univ., Honolulu.

#### CARBON RECYCLING IN MATERIALLY CLOSED ECOLOGICAL LIFE SUPPORT SYSTEMS

D. C. OBENHUBER and C. E. FOLSOME (Hawaii, University, Honolulu) BioSystems (ISSN 0303-2647), vol. 21, 1988, p. 165-173. Research supported by the University of Hawaii. refs (Contract NGR-12-001-109)  
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Results of studies are presented of materially closed energetically open microbial ecosystems or 'closed ecosystems'. These are natural marine ecosystems that have been sealed in glass containers to prevent material exchange with the environment but allow energy to pass freely through them. They represent model life support systems for the future human habitation of space. The results are discussed analytically and indicate that these ecosystems, when subjected to a constant energy flux, seem to be reliable and self-sufficient systems for recycling of biologically produced carbon compounds. S.A.V.

**A89-38259**

#### SPACE STATION AND MANNED SPACE TECHNOLOGY - WET CATALYTIC OXIDATION PROCESS FOR WASTEWATER TREATMENT IN CELSS

YOSHIAKI HARADA (Osaka Gas Co., Ltd., Research Center, Japan) in: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings, Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1701-1708.  
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This paper presents a technology for wastewater treatment and its recycling in the controlled ecological life of a space station. The catalytic wet oxidation process planned to be applied in the system is a method of wastewater treatment using a newly developed solid catalyst. By using the catalyst under high temperature and pressure (200-270 C, 40-90 kg/sq cm G), concentrated ammonia, COD (chemical oxygen demand), and BOD (biological oxygen demand) components and suspended solids in wastewaters can be simultaneously oxidized and treated with high efficiency in a single step without dilution. The pollutants are converted into harmless N<sub>2</sub>, CO<sub>2</sub> and H<sub>2</sub>O, and besides, the wastewater is decolorized, deodorized, and sterilized. Author

**A89-38260**

#### A GROUND EXPERIMENTAL MODEL OF WATER DISTILLATION SYSTEM BY THERMOPERVAPORATION FOR SPACE

KEIJI NITTA, KOJI OTSUBO, MITSUO OGUCHI, TOSHIHARU TANEMURA (National Aerospace Laboratory, Chofu, Japan), KENJI MITANI (Hitachi, Ltd., Space Systems Div., Yokohama, Japan) et al. in: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings.



Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1709-1712.  
Copyright

A ground experimental model of a water distillation system based on the thermopervaporation method has been constructed. The basic experiments with this model have been performed. It is shown that the permeating rate is 0.8 l/hr for an effective area of 0.28 sq m and the rejection rate of any components, except for ammonia, is greater than 96 percent (almost all of data show 100 percent rejection). Reduction of ammonia can be made by activated charcoal. Thus, the system has shown feasibility for space use.

Author

#### AB9-38262

##### CONCEPTUAL STUDY ON CARBONDIOXIDE REMOVAL, CONCENTRATION AND OXYGEN GENERATION SYSTEMS

KYOICHI MANABE (National Space Development Agency of Japan, Tokyo), TAKATOSHI SHOJI, HIROYUKI MATSUMURA, MASAO HAYASHITANI, TAIKI WATANABE (Kawasaki Heavy Industries, Ltd., Akashi, Japan) et al. IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings, Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1719-1724. refs

Copyright

This report deals with the Environmental Control and Life Support Systems (ECLSS) for manned space activities. In enclosed spacecraft, it is necessary to supply O<sub>2</sub> gas to crew members and to remove CO<sub>2</sub> gas in the cabin. If metabolic CO<sub>2</sub> gas can be reduced safely on orbit to carbon (C) and oxygen (O<sub>2</sub>), it will be possible to use O<sub>2</sub> gas efficiently, and the amount of O<sub>2</sub> to be carried will be greatly decreased. From the experimental studies conducted so far, the following results were obtained: (1) solid amine CO<sub>2</sub> adsorption method is most favorable for CO<sub>2</sub> removal; (2) both BOSCH and SABATIER methods can be used but the BOSCH method is more efficient in reducing CO<sub>2</sub> to H<sub>2</sub>O; and (3) the solid polymer electrolysis of water is the most preferable method for generating pure O<sub>2</sub> gas.

Author

#### AB9-38264

##### GAS BALANCING METHOD FOR MINIMIZING THE VOLUME OF O<sub>2</sub> AND CO<sub>2</sub> RESERVOIRS IN CELSS

KEIJI NITTA, KOJI OTSUBO, MITSUO OGUCHI, and TOSHIHARU TANEMURA (National Aerospace Laboratory, Chofu, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings, Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1731-1741. refs

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The gas balance in a CELSS-type closed system with a minimum reservoir capacity is shown to be achieved by controlling the photosynthetic reaction of plants via stabilization of the O<sub>2</sub> and CO<sub>2</sub> partial pressures. The stabilization of the gas environment using incineration and physicochemical oxygen recovery systems such as the Sabatier reaction is discussed. Also considered are the necessary and sufficient quantities of plant cultivation for supporting a one-man crew, the quantities of human waste and inedible plant parts generated in CELSS, and the oxygen requirements for human respiration and the oxidation of wastes and inedible plant parts.

R.R.

#### AB9-38265

##### CONSTRUCTION OF CLOSED ALGAL (SPIRULINA) CULTIVATION SYSTEM FOR FOOD PRODUCTION AND GAS EXCHANGE IN SPACE

MITSUO OGUCHI, KOJI OTSUBO, KEIJI NITTA (National Aerospace Laboratory, Chofu, Japan), ATSUSHI SHIMADA, SHIGEO FUJII (Toa Nenryo Kogyo, Corporate Research and Development Laboratory, Saitama, Japan) et al. IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings, Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1743-1749.

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A closed continuous algal (spirulina) cultivation system was constructed. Both carbon dioxide and medium supply to the culture and algal mass and oxygen separation from the culture were

conducted automatically by a computer, while the pressure inside the culture vessel was kept constant in the closed system. This model is a primary model for ground experiments before the experiments of culturing Spirulina in a Space Station. The feasibility of culturing Spirulina in a closed recycling system is discussed on the basis of data obtained by use of this new system.

Author

#### AB9-38277

##### LIFE SUPPORT SYSTEMS FOR EUROPEAN MANNED SPACE VEHICLES

A. INGEMAR SKOOG (Dornier System GmbH, Friedrichshafen, Federal Republic of Germany) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings, Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1831-1840.

Copyright

Life support systems (LSSs) for the Columbus module, the Hermes spaceplane, and the European EVA space suit are discussed. In the Columbus attached pressurized module, regenerative functions are provided for CO<sub>2</sub> removal (solid amine) and contamination control (a catalytic burner), and the International Space Station core element provides the supply of oxygen, nitrogen, and water. A nonregenerative concept is planned for ... CO<sub>2</sub> removal in Hermes. The European space suit LSS is an on loop design, with CO<sub>2</sub> removal by LiOH and thermal control by means of a condensing heat exchanger and sublimator.

R.R.

#### AB9-38278

##### JEM ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM

K. SHIRAKI, K. MANABE (National Space Development Agency of Japan, Tokyo), H. FUJIMORI, A. HATTORI, and H. HAMA (Kawasaki Heavy Industries, Ltd., Kobe, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings, Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1841-1850.

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As a result of the preliminary study for the Environmental Control and Life Support System (ECLSS) of the Japanese Experiment Module (JEM), the functions of the JEM ECLSS were defined as follows, considering accommodation for JEM various operation and system redundancy requirements: atmosphere control and supply, temperature and humidity control (including intramodule and intermodule air ventilation), atmosphere revitalization (CO<sub>2</sub> removal, contamination control and monitoring), fire detection and suppression, water management, and rescue provision.

Author

#### AB9-38279

##### IMPACT OF CONCENTRATED CARBON DIOXIDE PURITY ON SPACE STATION AIR INTEGRATION

ROSS J. CUSHMAN and TIMOTHY D. SCULL (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings, Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1857-1862.

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The impact of air (acting as an impurity in the concentrated CO<sub>2</sub>) on the advanced carbon reactor (ACR) and Bosch CO<sub>2</sub>-reduction subsystems, and other subsystems, of the ECLSS atmospheric revitalization system (ARS) have been quantified. It is shown that either of the CO<sub>2</sub> reduction technologies can be sized with respect to compressor capacity and operated to minimize the overall impact on the ARS of having less than 100 percent pure CO<sub>2</sub>. Optimized impacted ARS equipment power penalties range from as low as 65 watts (for 1 percent air entering the ACR system) to as high as 500 watts (for 4 percent air entering the Bosch system).

R.R.

#### AB9-38280

##### A STUDY ON THE AIR DIFFUSION PERFORMANCE FOR ENVIRONMENTAL CONTROL IN THE SPACE STATION

AKIRA MASUMOTO, TADASHI KOBAYASHI, HITOSHI IWASAKI (Kawasaki Heavy Industries, Ltd., Life Support Engineering Dept.,



Kobe, Japan), and MASATOSHI HIROKAWA (Kawasaki Heavy Industries, Ltd., Thermal Engineering Research Laboratory, Akashi, Japan). IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1863-1870. Copyright

In carrying out experiments in the experiment module of the Space Station, the crew members of scientist are in shirt sleeves. For the environmental control to obtain comfortable conditions under the non-gravitation in the Station, the air-diffusion performance is one of the fundamental performance factors. This paper describes simulation analyses on the air diffusion performance under the non-gravitation and the environmental control performance, and offers conclusions about the optimization of the air circulation system. Author

#### ABN-38281

##### A STUDY ON REMOVAL OF TRACE CONTAMINANT GASES

K. MANABE (National Space Development Agency of Japan, Tokyo), H. ITOH, S. MITSUDA, Y. KUBO (Kawasaki Heavy Industries, Ltd., Akashi, Japan), S. FUJITA (Kawasaki Heavy Industries, Ltd., Kobe, Japan) et al. IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1871-1876. Copyright

Over 200 trace gaseous contaminants have been detected in cabin atmospheres from manned spacecraft. Consequently, the Trace Contaminant Control System shall be provided as a subsystem of the Environmental Control and Life Support System in the Japanese Experiment Module (JEM) attached to the Space Station, and atmospheric contaminants shall be kept below their Maximum Allowable Concentration. An adsorption and catalytic oxidation process has been adopted as the most preferable technology by the JEM subsystem investigation implemented on the phase B preliminary study. Author

#### ABN-44296\* Texas A&M Univ., College Station.

##### ANALYSIS OF AN ALGAE-BASED CELSS. I - MODEL DEVELOPMENT

MARK T. HOLTZAPFLE, FRANK E. LITTLE, MERRY E. MAKELA, and C. O. PATTERSON (Texas A & M University, College Station) Acta Astronautica (ISSN 0094-5765), vol. 19, April 1989, p. 353-364. refs (Contract NAG9-161) Copyright

A steady state chemical model and computer program have been developed for a life support system and applied to trade-off studies. The model is based on human demand for food and oxygen determined from crew metabolic needs. The model includes modules for water recycle, waste treatment, CO<sub>2</sub> removal and treatment, and food production. The computer program calculates rates of use and material balance for food, O<sub>2</sub>, the recycle of human waste and trash, H<sub>2</sub>O, N<sub>2</sub>, and food production/supply. A simple noniterative solution for the model has been developed using the steady state rate equations for the chemical reactions. The model and program have been used in system sizing and subsystem trade-off studies of a partially closed life support system. Author

#### ABN-44297\* Texas A&M Univ., College Station.

##### ANALYSIS OF AN ALGAE-BASED CELSS. II - OPTIONS AND WEIGHT ANALYSIS

MARK T. HOLTZAPFLE, FRANK E. LITTLE, WILLIAM M. MOSES, and C. O. PATTERSON (Texas A & M University, College Station) Acta Astronautica (ISSN 0094-5765), vol. 19, April 1989, p. 365-375. refs (Contract NAG9-161) Copyright

Life support components are evaluated for application to an idealized closed life support system which includes an algal reactor for food production. Weight-based trade studies are reported as 'break-even' time for replacing food stores with a regenerative

biosector. It is concluded that closure of the life support gases (oxygen recovery) depends on the carbon dioxide reduction chemistry and that an algae-based food production can provide an attractive alternative to re-supply for longer duration missions. Author

#### ABN-45512

##### SOVIET SPACE FLIGHT - THE HUMAN ELEMENT

VICTORIA GARSHNEK Aviation, Space, and Environmental Medicine (ISSN 0095-4562), vol. 60, July 1989, p. 695-705. refs Copyright

The Soviet manned space missions between 1961 and 1988 are described, with emphasis on the third-generation space station Mir. Particular attention is given to the Soviet manned space program today, including the details of the cosmonaut preparation (selection, training, psychological selection/preparation, and medical training), physiological and psychological measures designed to counteract the effects of a long-term spaceflight (exercise programs, the Penguin suit, the Chibis suit/salt water loading/anti-G suit system, psychological support, nutrition, and the pharmacologic protection), and postflight recovery activities. I.S.

#### ABN-45807

##### SUPERCRITICAL WATER OXIDATION - SPACE APPLICATIONS

GLENN T. HONG, WILLIAM R. KILLALEA, and TERRY B. THOMASON (Modar, Inc., Natick, MA) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 987-998. refs Copyright

The process of supercritical water oxidation (SCWO) is approaching terrestrial commercialization for the destruction of toxic and hazardous waste chemicals. The technology appears promising for use in space applications, where its primary functions would be aqueous waste treatment, potable water product, and possibly facility atmosphere purification. The present paper discusses some of the considerations for the use of SCWO in space facilities. Author

#### ABN-45808\* Bend Research, Inc., OR.

##### DEVELOPMENT OF A TWO-STAGE MEMBRANE-BASED WASH-WATER RECLAMATION SUBSYSTEM

S. B. MCCRAY (Bend Research, Inc., OR) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 999-1010. refs (Contract NAS9-17031; NAS9-17523) Copyright

A two-stage membrane-based subsystem was designed and constructed to enable the recycle of wash waters generated in space. The first stage is a fouling-resistant tube-side-feed hollow-fiber ultrafiltration module, and the second stage is a spiral-wound reverse-osmosis module. Throughout long-term tests, the subsystem consistently produced high-quality permeate, processing actual wash water to 95 percent recovery. Author

#### ABN-45809

##### WASTE MANAGEMENT - PROJECT MERCURY TO THE SPACE STATION

ANTHONY WACHINSKI (U.S. Air Force Academy, Colorado Springs, CO) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 1011-1020. refs Copyright

The design of a waste management system for manned space flights is considered on the basis of the results of waste management studies published by NASA and other sources. The evolution of the waste management system is followed, from the systems on board the Project Mercury and Project Gemini through Apollo, Skylab, and Space Shuttle Orbiter, with particular

## 05 ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEMS

consideration given to the waste collection, waste management, water management, and storage subsystems. The constraints on the special features in the design of the Space Station waste management system are examined. I.S.

**A89-45810**

### PLASMA REACTOR WASTE MANAGEMENT SYSTEMS

ROBERT O. NESS, JR., JOHN R. RINDT, and SUMITRA R. NESS (North Dakota, University, Grand Forks) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 1021-1032. refs. Copyright

The development of a plasma reactor system for use in closed-loop processing of biological, manufacturing, and waste materials, is discussed. The system uses dc, high-frequency, or microwave discharges to produce plasmas for treating the materials. A batch plasma reactor was used to oxidize human fecal material, sunflowers, oats, soybeans and plastics. The system converted over 98 percent of the organic material to gaseous products. Analysis of the remaining solids showed large amounts of water and acid-soluble materials that could possibly be used as nutrients for biological systems. R.B.

**A89-45811**

### WASTEWATER RECYCLE/REUSE - LESSONS-LEARNED FROM USA-CERL RESEARCH AND DEVELOPMENT

RICHARD J. SCHOLZE, JR. and ED D. SMITH (U.S. Army, Construction Engineering Research Laboratory, Champaign, IL) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 1033-1043. refs. Copyright

Ultimate acceptance of water recycle/reuse by the scientific community is a function of rigorous data collection and successful demonstration regarding health effects. An uncomplicated, workable field laundry and shower wastewater recycling system with the potential to save substantial amounts of water under arid field conditions has been developed. Development of the system has been paralleled by a primary focus on the health considerations of using the recycled water. Direction for future research and development is presented in a generic format to ensure appropriate data are collected to answer health related questions. Author

**A89-54249**

### THE BLUE COLLAR SPACESUIT

JOHN GROSSMANN Air and Space (ISSN 0886-2257), vol. 4, Oct.-Nov. 1989, p. 58-67. Copyright

The development of a spacesuit to be used aboard the Space Station is examined. The designs of two spacesuits, which must be capable of onboard maintenance and servicing, are described. The AX-5 is aluminum, contains no fabric, and weighs 185 lbs. The Mark III is 65 pct metal and 35 pct fabric and weighs 155 lbs. Both suits have rear entry, bubble helmets, stainless steel bearings, and Ortman rings for coupling and decoupling suit segments. The testing of the two spacesuits in the Weightless Environment Training Facility is discussed. I.F.

**A89-54375\*** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

### SUSTAINING HUMANS IN SPACE

G. SCOTT HUBBARD and ALAN R. HARGENS (NASA, Ames Research Center, Moffett Field, CA) Mechanical Engineering (ISSN 0025-6501), vol. 111, Sept. 1989, p. 40-44. Copyright

NASA research on the functioning of biological systems in space and the resulting improvement in space suits and life-support systems is discussed. The centrifuge facility which will provide the major elements of a life science research facility for Spacelab and Space Station Freedom is described, and the Vestibular Research Facility for studying motion sickness in space is

examined. The aluminum AX-5 space suit and the Controlled Ecological Life-Support System are described, and biomedical sensors for studying bone mass changes in space are discussed. Studies on the use of exercise to control tissue-fluid shifts in space are described. C.D.

**N89-23063#** Severn Communications Corp., Millersville, MD. **ASTRONAUT RADIATION EXPOSURE IN LOW-EARTH ORBIT. PART 1: GALACTIC COSMIC RADIATION**

JOHN R. LETAW 31 Mar. 1988 45 p (Contract N00014-87-C-2251) (AD-A204598; SOC-88-01) Avail: NTIS HC A03/MF A01 CSCI 06/7

In recent years, there has been increasing concern about the radiation doses which will be suffered by astronauts on present-day and future space missions. In order to characterize radiation exposure risks on space missions one requires models of space radiation environments, codes for transporting the components of ionizing radiation, and procedures for assessing radiation risks of a given exposure. To verify their accuracy, predictions based on these transport results must then be compared with existing dosimetry data. Linear energy transfer (LET) spectra, absorbed dose, and dose equivalent from galactic cosmic radiation and its fragments are presented for four, representative low-earth orbit configurations. The orbits include a high (STS-51J) and low (STS-61C) altitude, low-inclination (28.5 degs) flight; a high inclination (49.5 degs) flight (STS-51F); and a polar flight. Results are compared with computations for an exo-magnetospheric flight. GRA

**N89-23503\*** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.

### SPACE STATION CMIF EXTENDED DURATION METABOLIC CONTROL TEST Final Report

RICHARD G. SCHUNK, ROBERT M. BAGDIGIAN, ROBYN L. CARRASQUILLO, KATHRYN Y. OGLE, and PAUL O. WIELAND Mar. 1989 190 p (NASA-TM-100362; NAS 1.15:100362) Avail: NTIS HC A09/MF A01 CSCI 22/2

The Space Station Extended Duration Metabolic Control Test (EMCT) was conducted at the MSFC Core Module Integration Facility. The primary objective of the EMCT was to gather performance data from a partially-closed regenerative Environmental Control and Life Support (ECLS) system functioning under steady-state conditions. Included is a description of the EMCT configuration, a summary of events, a discussion of anomalies that occurred during the test, and detailed results and analysis from individual measurements of water and gas samples taken during the test. A comparison of the physical, chemical, and microbiological methods used in the post test laboratory analyses of the water samples is included. The preprototype ECLS hardware used in the test, providing an overall process description and theory of operation for each hardware item. Analytical results pertaining to a system level mass balance and selected system power estimates are also included. Author

**N89-24044\*** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.

### SPACE STATION ECLSS SIMPLIFIED INTEGRATED TEST Final Report

RICHARD G. SCHUNK, ROBERT M. BAGDIGIAN, ROBYN L. CARRASQUILLO, KATHRYN Y. OGLE, and PAUL O. WIELAND Mar. 1989 42 p (NASA-TM-100363; NAS 1.15:100363) Avail: NTIS HC A03/MF A01 CSCI 06/11

A discussion of the Space Station Simplified Integrated Test (SIT) was conducted. The first in a series of three integrated Environmental Control and Life Support (ECLS) system tests, the primary objectives of the SIT were to verify proper operation of ECLS subsystems functioning in an integrated fashion as well as to gather preliminary performance data for the partial ECLS system used in the test. A description of the SIT configuration, a summary of events, a discussion of anomalies that occurred during the

test, and detailed results and analysis from individual measurements and water and gas samples taken during the test are included. The preprototype ECLS hardware used in the test is reported providing an overall process description and theory of operation for each hardware item. Author

**N89-24354#** Domier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.).

#### ECLS FOR COLUMBUS AND HERMES

H. PREISS, G. KRING, and R. SCHAEFER In ESA, International Symposium on Europe in Space: The Manned Space System p 163-167 Oct. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The environment control and life support subsystems (ECLS) of Hermes and Columbus are presented. The Hermes ECLS system has to ensure adequate working conditions for three persons during a 12 day mission. It includes atmosphere, liquids, food/galley, and waste management subsystems. The Columbus ECLS supports scientific experiments in an unmanned mode for 180 days, plus 7 days servicing with 2 persons. The ECLS functions for Columbus are mainly concerned with atmosphere control and conditioning.

ESA

**N89-24369#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst. for Aerospace Medicine.

#### MEDICAL AND RADIATION PROTECTION PROBLEMS IN SPACE

K. E. KLEIN and H. BUECKER In ESA, International Symposium on Europe in Space: The Manned Space System p 291-302 Oct. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

Possibilities of inflight disturbances to space missions due to diseases, operation, and environment are discussed. Equipment needed for diagnosis and treatment is considered. Countermeasures are considered. Research required on the radiation hazard to space crews is suggested, including the measurement of radiation in space, the determination of its biological significance, and the establishment of radiation protection standards and of a system of dosimetric surveillance. ESA

**N89-24506#** National Aerospace Lab., Tokyo (Japan).

#### AN ATOMIC OXYGEN GENERATION FACILITY FOR SPACE ENVIRONMENTAL TESTINGS

YASUO WATANABE, YOSHINORI FUJIMORI, and MICHIO NISHIDA Aug. 1988 16 p In JAPANESE; ENGLISH summary (NAL-TR-989; ISSN-0389-4010) Avail: NTIS HC A03/MF A01

Preliminary experiments in producing atomic oxygen for space environmental testings were conducted. O-atoms were generated by injecting molecular oxygen into a preionized argon plasma. A mixture of argon plasma and oxygen was expanded through a sonic orifice into a low pressure chamber as a free jet. To confirm the generation of O-atoms and to examine the possibility of forming a molecular beam from the supersonic free jet, population densities of the electronic excitation levels  $3p(3)P$  and  $3p(5)P$  of atomic oxygen were measured along the free jet centerline. The population densities satisfied the flux condition of low earth orbit. Author

**N89-24790#** National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, TX.

#### A METHOD OF ISOLATING TREADMILL SHOCK AND VIBRATION ON SPACECRAFT

WILLIAM E. THORNTON Apr. 1989 18 p (NASA-TM-100474; S-591; NAS 1.15:100474) Avail: NTIS HC A03/MF A01 CSCL 06/19

A major problem is currently felt to exist in the implementation of materials processing on a spacecraft. Crystal growers place requirements of one micro-g or less on the vehicle. Simple math produces startling figures for such a restriction e.g., for each ton of vehicle mass with  $10(-6)$  g acceleration limit; Perturbing Force limit,  $F = .002$  lb. For each  $10(5)$  lbs  $F = 0.1$  lb. For each  $10(6)$

lbs  $F = 1.0$  lb. Forces generated by normal human movement on spacecraft of  $5 \times 10(5)$  pounds weight are on an order-of-magnitude greater than allowed by this specification and forces generated by locomotion on a treadmill are more than two orders-of-magnitude greater. Other exercises and normal onboard functions generate forces in between. To accommodate many essential functions it is obvious that even on a vehicle as large as Space Station, a reduction of more than two orders of magnitude in force is required. Commonly used passive shock and vibration isolation devices are complex, heavy, and also would have difficulty meeting the requirements. However, by a new arrangement, adequate isolation can be obtained. Isolation of the treadmill will be treated since it is considered the most significant disturbance at this time.

Author

**N89-25561#** Alabama A & M Univ., Normal.

#### CHARACTERIZATION OF SPIRULINA BIOMASS FOR CELSS DIET POTENTIAL

MAHASIN G. TADROS Oct. 1988 53 p

(Contract NCC2-501)

(NASA-CR-185329; NAS 1.26:185329) Avail: NTIS HC A04/MF A01 CSCL 06/3

Spirulina sp. as a bioregenerative photosynthetic and an edible alga for space craft crew in a CELSS, was characterized for growth rate and biomass yield in batch cultures, under various environmental conditions. The cell characteristics were identified for two strains of Spirulina: *S. maxima* and *S. plantensis*. Fast growth rate and high yield of both strains were obtained under the following conditions: temperature (30 to 35 C), light irradiance (60 to 100  $\mu E/m^2/s$ ), nitrate (30 mM), phosphate (2 mM), aeration (300 ml/min), and pH (9 to 10). The partitioning of the assimilatory products (proteins, carbohydrates, lipids) were manipulated by varying the environmental growth conditions. The experiments with Spirulina demonstrated that under stress conditions (high light 120  $\mu E/m^2/s$ , temperature 38 C, nitrogen or phosphate limitation; 0.1 M sodium chloride) carbohydrate increased at the expense of protein. In other experiments, where the growth media were sufficient in nutrients and incubated under optimum growth conditions, the total proteins were increased up to almost 70 percent of the organic weight. Conclusion: The nutritional quality of the alga could be manipulated by growth conditions, and therefore useful as a subsystem in CELSS. Author

**N89-26398#** National Aeronautics and Space Administration, Ames Research Center, Moffett Field, CA.

#### RESULTS AND APPLICATIONS OF A SPACE SUIT RANGE-OF-MOTION STUDY

AL REINHARDT Jul. 1989 16 p Presented at the SAE Intersociety Conference on Environmental Systems, Moffett Field, CA, 24-27 Jul. 1989

(NASA-TM-102204; A-89164; NAS 1.15:102204) Avail: NTIS HC A03/MF A01 CSCL 05/8

The range of motion of space suits has traditionally been described using limited 2-D mapping of limb, torso, or arm movements performed in front of an orthogonal grid. A new technique for recovering extra-vehicular (EVA) space suit range-of-motion data during underwater testing was described in a paper presented by the author at the 1988 conference. The new technique uses digitized data which is automatically acquired from video images of the subject. Three-dimensional trajectories are recovered from these data, and can be displayed using 2-D computer graphics. Results of using this technique for the current shuttle EVA suit during underwater simulated weightlessness testing are discussed. Application of the data for use in animating anthropometric computer models is highlighted. Author

**N89-26540#** Stanford Univ., CA.

#### REPORT ON THE STANFORD/AMES DIRECT-LINK SPACE SUIT PREHENSOR

J. W. JAMESON and LARRY LEIFER In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telebotanics, Volume 2 p 433-442 1 Jul. 1987 Sponsored by



NASA, Ames Research Center

Avail: NTIS HC A18/MF A03 CSDL 05/8

Researchers at the Center for Design Research at Stanford University, in collaboration with NASA Ames at Moffet Field, California, are developing hand-powered mechanical prehensors to replace gloves for EVA spacesuits. The design and functional properties of the first version Direct Link Prehensor (DLP) is discussed. It has a total of six degrees-of-freedom and is the most elaborate of three prehensors being developed for the project. The DLP has a robust design and utilizes only linkages and revolute joints for the drive system. With its anthropomorphic configuration of two fingers and a thumb, it is easy to control and is capable of all of the basic prehension patterns such as cylindrical or lateral pinch grasps. Kinematic analysis reveals that, assuming point contacts, a grasped object can be manipulated with three degrees-of-freedom. Yet, in practice more degrees-of-freedom are possible. Author

**N89-26215\*** National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, AL.

## STATUS OF THE US SPACE STATION ECLSS AND INTERNAL TCS

R. HUMPHRIES, L. TURNER, J. REUTER, and D. PATTERSON  
In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 5-13 Dec. 1988

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The space station environmental control and life support system (ECLSS) and internal thermal control system (ITCS) are outlined. The ECLSS is composed of six subsystem groups: the temperature humidity control, the atmosphere control and supply, the air revitalization, water reclamation and management, fecal waste management, and the fire detection and suppression subsystems. The ITCS consists of all WP01 elements of passive and active thermal measures. The ECLSS and ITCS provide services for the permanently orbiting pressurized modules as well as the pressurized and unpressurized logistics carriers. All internal cooling of the permanent orbital elements are provided via internal active fluid loops within the elements utilizing water as the transport media. Cabin and equipment cooling are provided by forced air flow and coldplate heat sinks. An active cooling loop is provided in the laboratory module to accommodate experiments and other payloads. Coatings and insulation are used in conjunction with the active components to passively limit heat losses/gains. The most challenging ECLSS new technology issues relate to oxygen and water recovery. Closure of the oxygen loop requires the use of regenerative CO<sub>2</sub> removal and concentration techniques, CO<sub>2</sub> reduction to convert the CO<sub>2</sub> to water with a waste by-product, and the electrolysis of water to produce breathing oxygen for water recovery. ESA

**N89-26219\*** Dornier System G.m.b.H., Friedrichshafen (Germany, F.R.).

## ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEMS FOR PRESSURIZED MODULES: FROM SPACELAB TO COLUMBUS

K.-O. HIENERWADEL and G. KRING In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 45-50 Dec. 1988

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The Columbus environmental control and life support system (ECLSS) is compared with the Spacelab ECLSS. The individual Columbus ECLSS equipment characteristics are identified, stating whether they are identical, modified, and advanced or completely new compared to the Spacelab capabilities. Although the basic ECLSS functions of Columbus are similar to those of Spacelab there are considerable differences in design and performance between the two systems. These differences are mainly caused by two factors. The first one is the mission duration characterized by the in orbit life time of the module and the uninterrupted

attendance of one crew before change of shift. The second one is the required full automatic operation capability caused by the 180 days free flying and unmanned period of the Man-Tended Free Flyer. ESA

**N89-26220\*** Dornier System G.m.b.H., Friedrichshafen (Germany, F.R.).

## THE DEFINITION STATUS OF THE ENVIRONMENTAL CONTROL AND LIFE SUPPORT SUBSYSTEMS FOR HERMES

R. SCHAEFER In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 51-55 Dec. 1988  
Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

The status of the Hermes environmental control and life support system (ECLSS) and the main differences compared with the Spacelab ECLSS are outlined. Requirements development from Phase A (6 men, 2 volumes) to Phase B (3 men, 3 volumes) and the relevant configurations are described. The atmosphere pressure control section; air conditioning section; liquid management section; food galley management section; hygiene and solid waste management section; and monitoring, control, and power management section are described. ESA

**N89-26221\*** Nelson Space Services Ltd., London (England).

## PHYSICO-CHEMICAL ATMOSPHERE REVITALISATION: THE QUALITATIVE AND QUANTITATIVE SELECTION OF REGENERATIVE DESIGNS

R. C. HUNTENBACH, A. R. KAISER, J. D. RADFORD, and R. A. BINOT (European Space Agency, European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 57-64 Dec. 1988

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The systems engineering needs of regenerative physico-chemical atmosphere revitalization is discussed from the qualitative point of view, and a procedure that can be used to quantify the prospective merits of competing designs at an early stage in their development cycle is described. This procedure involves the preparation of energy and multicomponent material balances, the derivation of weight penalties for various power generation/supply and heat rejection technologies, the calculation of equivalent weights versus duration of mission and the use of spreadsheets to analyze the sensitivity of results when input data such as the weight of flight qualified equipment is subject to uncertainty. The methodology can be applied to other systems including water management and future biological options on manned space missions. ESA

**N89-26222\*** Centre d'Etude de l'Energie Nucleaire, Mol (Belgium).

## MELISSA: A MICRO-ORGANISMS-BASED MODEL FOR CELSS DEVELOPMENT

M. MERGEAY, W. VERSTRAETE, G. DUBERTRET, M. LEFORT-TRAN, C. CHIPPAUX, and R. A. BINOT (European Space Agency, European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 65-68 Dec. 1988

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The MELISSA was conceived as a microorganism based ecosystem, being a simplified, model of a future biological life support system for manned missions. The driving element is the reprocessing of edible biomass from waste, CO<sub>2</sub>, and minerals with the direct use of sunlight as a source of energy for biological photosynthesis. A four compartments ecosystem is selected allowing the closure of the material loop around a central food and O<sub>2</sub> reprocessing compartment by the growth of the filamentous cyanobacterium SPIRULINA. Nitrates, CO<sub>2</sub>, and minerals required

by SPIRULINA are produced by the other microbial compartments, namely an anaerobic digestion system and a nitrifying compartment. The anaerobic digestion system includes a thermophilic solubilization and fermentation compartment (CLOSTRIDIA) followed by a second light dependent compartment, colonized by RHODOBACTER, removing the soluble organics (mainly fatty acids) and leaving the minerals requested by SPIRULINA, and producing a biomass of high food value. Nitrification of ammonium from the anaerobic step to nitrate for SPIRULINA, is performed by NITROBACTERIA, with a very low biomass production, in the fourth compartment. For a consumer added to the loop, MELISSA ensures food and oxygen recycling through complete carbon, nitrogen, sulfur and minerals cycles, driven in axenic conditions by genetically well-known, nonpathogenic strains. ESA

**N89-28237#** Dornier System G.m.b.H., Friedrichshafen (Germany, F.R.).

#### REGENERATIVE CO<sub>2</sub>-CONTROL

H. PREISS and H. FUNKE In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 177-183 Dec. 1988 Sponsored by the Bundesministerium fuer Forschung und Technologie, Bonn, Fed. Republic of Germany Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

Technological work for a regenerative CO<sub>2</sub>-control system, applicable for longterm space missions, especially the Columbus program, is described. Regenerative CO<sub>2</sub>-control is required for this program, because the previous use of expendable chemical agents as applied for Spacelab leads to unacceptable mass and volume penalties. In regenerative CO<sub>2</sub>-control, the adsorber material can accumulate and release CO<sub>2</sub> in a periodic way. However the regeneration process needs energy, which is not necessary for the expendables. Major design parameters, which allow the sizing and interface definition of a regenerative CO<sub>2</sub>-control for an actual space application were derived. This is demonstrated by the successful operation of an advanced breadboard, where predicted and measured performance are in good agreement. Two adsorber materials were tested, showing adequate performance. The research material has better stability than the commercial product and is the favored material. ESA

**N89-28238#** Draegerwerk A.G., Luebeck (Germany, F.R.).

#### ELECTROCHEMICAL REMOVAL AND CONCENTRATION OF CO<sub>2</sub>

S. HAUPT In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 185-186 Dec. 1988 Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

It is argued that because electrochemical reactions can be performed with high power efficiencies, and because of the direct transfer of the removed CO<sub>2</sub> into hydrogen, the electrochemical method has advantages in comparison to other methods, when requirements such as power consumption, efficiency, mass and volume are concerned. An electrochemical assembly similar to a fuel cell can meet the requirements for CO<sub>2</sub> removal in space application. For the construction of an effective system for CO<sub>2</sub> removal and concentration, all electrode processes and transport mechanisms have to be studied in detail. Using ion selective membranes, the transport processes can be controlled effectively. ESA

**N89-28239#** Draegerwerk A.G., Luebeck (Germany, F.R.).

#### THE CATALYTIC OXIDIZER: DESCRIPTION AND FIRST RESULTS OF A BREADBOARD MODEL FOR A COMPONENT OF THE COLUMBUS ECLSS

K. AMMANN In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 187-192 Dec. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

A technological breadboard of a catalytic oxidizer system was designed to remove the low boiling point hydrocarbons, hydrogen, and carbon monoxide from a space station atmosphere. With respect to the necessary flow rate, CO turned out to be the design driver, while CH<sub>4</sub> (which needs a flow rate significantly lower than CO) is the design driver for the temperature required. For energy saving, a two catalyst system which consists of a high flow/low temperature catalyst for CO oxidation and a low flow/high temperature catalyst for the oxidation of methane, hydrogen and the other candidate contaminants was chosen. Results of performance tests including experiments with selected catalyst poisons are discussed. ESA

**N89-28240#** Nord-Micro Elektronik Feinmechanik G.m.b.H., Frankfurt (Germany, F.R.).

#### CONDENSING HEAT EXCHANGERS FOR EUROPEAN SPACECRAFT ECLSS

P. KUHN and F. PETTER In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 193-197 Dec. 1988 Sponsored by the Bundesministerium fuer Forschung und Technologie, Bonn, Fed. Republic of Germany and Aérospatiale, France Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

Based on an earlier concept, a condensing heat exchanger type with lower complexity and reduced weight and volume compared with previous configurations was developed. Probe units with extremely low leakage were obtained both by careful selection of materials and processes and close control of manufacturing parameters. Hydrophilic coatings on the basis of borosilicate glass and polysilicate ceramic, providing wettable surfaces to the air passes and slurpers of condensing heat exchangers were developed. ESA

**N89-28244#** European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).

#### LIFE SUPPORT FOR EVA: THE EUROPEAN SYSTEM BASELINE

J. WITT, B. SVENSSON, and R. VAETH (Dornier System G.m.b.H., Friedrichshafen, Germany, F.R.) In its Third European Symposium on Space Thermal Control and Life Support Systems p 221-226 Dec. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

Based on earlier system studies the EVA Life Support Module (ELSM) was studied. A review of metabolic design factors set the performance limits of the ELSM. Various design solutions for the physical realization of the ELSM functions were studied and traded-off against each other. The design baseline for the ELSM established is presented. The further development of life support for EVA in Europe is timed for a first manned flight of Hermes in 1999. ESA

**N89-29020\*#** Massachusetts Inst. of Tech., Cambridge. Space Systems Lab.

#### SPACECRAFT FLIGHT SIMULATION: A HUMAN FACTORS INVESTIGATION INTO THE MAN-MACHINE INTERFACE BETWEEN AN ASTRONAUT AND A SPACECRAFT PERFORMING DOCKING MANEUVERS AND OTHER PROXIMITY OPERATIONS

ADAM R. BRODY Sep. 1988 97 p

(Contract NAGW-21)

(NASA-CR-177502; NAS 1.26:177502) Avail: NTIS HC A05/MF A01 CSCL 05/9

The anticipated increase in rendezvous and docking activities in the various space programs in the Space Station era necessitates a renewed interest in manual docking procedures. Ten test subjects participated in computer simulated docking missions in which the influence of initial velocity was examined. All missions started from a resting position of 304.8 meters (1000 feet) along the space

station's +V-bar axis. Test subjects controlled their vehicle with a translational hand controller and digital auto pilot which are both virtually identical to their space shuttle counterparts. While the 0.1 percent rule (range rate is equal to 0.1 percent of the range) used by space shuttle pilots is comfortably safe, it is revealed to be extremely inefficient in terms of time and not justifiable in terms of marginal safety. Time is worth money, not only because of training and launch costs, but because the sooner a pilot and spacecraft return from a mission, the sooner they can begin the next one. Inexperienced test subjects reduced the costs of simulated docking by close to a factor of 2 and achieved safe dockings in less than 4 percent of the time the baseline approach would entail. This reduction in time can be used to save lives in the event of an accident on orbit, and can tremendously reduce docking costs if fuel is produced from waste water on orbit.

Author

## 06

## DYNAMICS AND CONTROLS

Includes descriptions of analytical techniques and computer codes, trade studies, requirements and descriptions of orbit maintenance systems, rigid and flexible body attitude sensing systems and controls such as momentum wheels and/or propulsive schemes.

## A89-33096#

**THE SOLAR PRESSURE TORQUE AND THE DESIGN OF THE ATTITUDE CONTROL SYSTEM OF THE COMMUNICATION SATELLITE WITH LARGE ANTENNA REFLECTORS**

MASAZUMI UEBA. Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 37, no. 420, 1989, p. 14-20. In Japanese, with abstract in English. refs

In this paper, the solar pressure torque of the 2-ton class satellite with two antisymmetric antenna reflectors was calculated. Then, the structure which causes large solar pressure torque was considered numerically. Based on the results, especially the secular and periodical component of the roll/yaw plane solar pressure torque, it was revealed, how to decide the magnitude of the bias momentum of the bias momentum attitude control system from the point of yaw error requirement. It was confirmed that simulation values agree well with the theoretical results.

Author

## A89-35026\*

**RECENT ADVANCES IN CONTROL OF NONLINEAR AND DISTRIBUTED PARAMETER SYSTEMS, ROBUST CONTROL, AND AEROSPACE CONTROL APPLICATIONS; PROCEEDINGS OF THE SYMPOSIUM, ASME WINTER ANNUAL MEETING, CHICAGO, IL, NOV. 27-DEC. 2, 1988**

JOSEPH BENTSMAN, ED. (Illinois, University, Urbana) and SURESH M. JOSHI, ED. (NASA, Langley Research Center, Hampton, VA) Symposium sponsored by ASME, Dynamic Systems and Controls Division. New York, American Society of Mechanical Engineers, 1988, 214 p. For individual items see A89-35027 to A89-35048.

Copyright

Papers are presented on the control of distributed parameter systems using the coprime factorization approach, a hierarchy of geometrically exact models of rotating beams, and the temperature stability of a flux modulated radiant slab. Also considered are a network representation for robots, recovery from controller bounding, and the design of controllers for robust tracking and model following. Other topics include an active control law synthesis for flexible aircraft, the low-order control of large aerospace structures using residual model filters, and a comparison of component cost methods for component model reduction. R.R.

## A89-35029#

**NONLINEAR FINITE-DIMENSIONAL CONTROL OF A CLASS OF NONLINEAR DISTRIBUTED PARAMETER SYSTEMS USING RESIDUAL MODE FILTERS**

M. J. BALAS (Colorado, University, Boulder) IN: Recent advances in control of nonlinear and distributed parameter systems, robust control, and aerospace control applications; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 19-21. refs

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In any attempt to control an infinite-dimensional distributed parameter system (DPS) with a finite-dimensional controller, some compensation for deleterious controller interaction with unmodeled modes is needed. The concepts of both a finite-dimensional nonlinear controller based on any reasonable, nonlinear reduced-order model of the DPS and stability compensation by a finite-dimensional, nonlinear residual mode filter are introduced. Under appropriate Lipschitz continuity conditions on the nonlinearities, this new pair of interconnected finite-dimensional systems will produce closed-loop (exponentially) stable control of the nonlinear DPS.

Author

**A89-35041\*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.**

**ROBUST CONTROLLER SYNTHESIS FOR LARGE FLEXIBLE SPACE STRUCTURES**

S. M. JOSHI, L. F. ROWELL, and E. S. ARMSTRONG (NASA, Langley Research Center, Hampton, VA) IN: Recent advances in control of nonlinear and distributed parameter systems, robust control, and aerospace control applications; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 147-155. refs

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The application of a multivariable frequency domain method for the attitude control and vibration suppression of large flexible space structures is discussed. Results of application of the linear-quadratic-Gaussian/loop transfer recovery method to the cases of a hop/column antenna, a wrap-rib antenna, and the Spacecraft Control Laboratory Experiment are presented. Controller order reduction is implemented using the balanced realization method, a Hankel-norm-based method, and a method based on stable factorization.

R.R.

## A89-35042#

**LOW-ORDER CONTROL OF LARGE AEROSPACE STRUCTURES USING RESIDUAL MODE FILTERS**

M. J. BALAS, R. QUAN, R. DAVIDSON, and B. DAS (Colorado, University, Boulder) IN: Recent advances in control of nonlinear and distributed parameter systems, robust control, and aerospace control applications; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 157-165. Research supported by the Engineering Foundation. refs

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A residual mode filter (RMF) design approach and a low-order controller have been applied to a realistic structure data base from a three-dimensional triangular cross-section truss. A controller, designed based on a reduced-order model of the structure, is connected in closed loop with a large-scale finite element model of the structure. The RMF is introduced into the loop to remove residual-mode instabilities appearing due to unwanted controller/structure interaction.

R.R.

## A89-35395#

**OPTIMAL STABILIZATION OF HYBRID DYNAMICAL SYSTEMS**

CHENG MU and DECHANG ZHANG (Northwestern Polytechnical University, Xian, People's Republic of China) Northwestern Polytechnical University, Journal (ISSN 1000-2758), vol. 7, April 1989, p. 165-170. In Chinese, with abstract in English. refs

This paper presents a theorem for the optimal stabilization of a hybrid dynamical system consisting of a discrete system and a



distributed parameter system. The hybrid dynamical system theorem can also be applied to both components of the hybrid, the discrete systems and the distributed parameter systems. The application of the theorem to the optimal stabilization problem is illustrated using a system composed of controlled rigid bodies and elastic bodies.

I.S.

A89-38836#

# DESIGN OF A PAYLOAD POINTING CONTROL SYSTEM FOR TRACKING MOVING OBJECTS

HARI B. HABLANI (Rockwell International Corp., Seal Beach, CA) *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090), vol. 12, May-June 1989, p. 365-374. refs

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A payload pointing control system for tracking an arbitrarily moving object is presented. The angular position, rate, and acceleration commands are developed in order for a two-degree-of-freedom telescope to track the object. The bandwidth of the control system is determined on the basis of the Fourier spectra of the rate commands and rate error specifications. The pointing control system operates in three modes: a linear rate mode for tracking, a linear position mode for settling, and a nonlinear position mode for coasting. The rate mode is a high bandwidth system (1.6 Hz), uses inertial rate commands, and consists of a double proportional-plus-integral (PI) controller. The position mode comprises the closed-loop rate mode and an additional PI controller; it works on relative position commands and has low bandwidth (0.32 Hz). The steady-state rate and position errors involve spectral density of the commands and the transfer functions of the controllers. The analysis is illustrated for a landmark observation with a near-Earth spacecraft. The settling times and steady-state errors based on single-axis and dominant pole approximations are compared with those from an extensive nonlinear digital simulation.

Author

A89-37507

# NUMERICAL ESTIMATES OF SECULAR EFFECTS IN THE TRANSLATIONAL-ROTATIONAL MOTION OF AN ORBITAL STATION WITH ARTIFICIAL GRAVITY (CHISLENNYE OTSENKI VEKOYKH EFFEKTOV V POSTUPATEL'NO-VRASHCHATEL'NOM DVIZHENII ORBITAL'NOI STANTSII, OBLADAIUSHCHEI ISKUSSTVENNOI TIAZHESTIU)

D. Z. KOENOV (Tadzhikskii Gosudarstvennyi Universitet, Dushanbe, Tadzhik SSR) *Akademiia Nauk Tadzhikskoi SSR, Doklady* (ISSN 0002-3469), vol. 31, no. 10, 1988, p. 644-646. In Russian.

Copyright

The coefficients of the secular terms in the translational-rotational motion of an orbital station with artificial gravity were determined. It is shown that the mean anomaly  $M = 1$  of the mass center of the station for every mean solar day increases by about 5179.25 deg. This indicates that the station makes more than 14 revolutions about the earth in the course of a mean solar day.

B.J.

A89-37646

# VOICE OF AUTHORITY

PETER DONALDSON *Space* (ISSN 0267-954X), vol. 5, Mar.-Apr. 1989, p. 13, 14.

Copyright

The development of voice control systems for use on space vehicles is discussed. French testing of a voice control system on the Mirage III aircraft is examined. Possible applications of the system include the Hermes, EVA on the Space Shuttle, and construction and maintenance on the Space Station. The ways in which voice control technology may be used to reduce astronaut workload are summarized. Issues related to the development of voice control systems are considered, including voice dependency, changes in voice patterns, speed, accuracy, and verifying commands.

R.B.

A89-37822

# DETECTION DELAYS, FALSE ALARM RATES AND THE RECONFIGURATION OF CONTROL SYSTEMS

M. MARITON (Matra, S.A., Velizy-Villacoublay, France) *International Journal of Control* (ISSN 0020-7179), vol. 49, March 1989, p. 981-992. refs

(Contract DRET-86-1391)

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The dynamic behavior of fault-tolerant controllers for complex systems such as large space structures and unstable aircraft is investigated analytically, with a focus on the role of fault-detection and isolation (FDI) devices. The case of a linear plant with random jumps in parameter values is considered, and the interactions between the FDI device and the control-gain reconfiguration are modeled using a hybrid scheme with continuous dynamics coupled to a discrete random process. It is shown that even short FDI detection delays or low false-alarm rates can produce stochastic instability when the estimated behavior is fed back into the closed-loop reconfiguration device. Techniques for overcoming this problem are briefly considered.

T.K.

A89-38100

# STRUCTURAL CONTROL BY USING ACTIVE TENDON CONTROL SYSTEM

H. OKUBO, Y. MUROTSU, K. SENDA (Osaka Prefecture University, Sakai, Japan), F. TERUI, and K. SHINODA. IN: *International Symposium on Space Technology and Science*, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 559-564. refs

Copyright

Modern modal control is applied to the design of an experimental tendon control system for a flexible beam. Two different approaches are proposed for realizing a stable reduced-order controller. One is an ordinary low-authority/high-authority control design, and the other uses highly flexible tension cables (tendons) for avoiding spillovers. The robust stability of the closed-loop system is verified for both designs by using a higher-order mathematical model with additional structural modes truncated in the controller design. In the latter approach, flexibility of the tendons is designed so that the tendon actuator system works as a mechanical frequency-shaping filter providing the plant with a high-frequency roll-off.

Author

A89-38108

# DYNAMICS OF SPINNING SPACECRAFT WITH FLEXIBLE RADIAL WIRE ANTENNAS

MOTOKI HINADA, ICHIRO NAKATANI, KEIKEN NINOMIYA, MAKOTO KUNUGI (Institute of Space and Astronautical Science, Sagami, Japan), NOBORU MURANAKA (NEC Corp., Space Development Div., Yokohama, Japan) et al. IN: *International Symposium on Space Technology and Science*, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 613-618.

Copyright

The dynamics of a spinning satellite with four radial wire antennas is studied. A generalized model is used in which the mass properties of wire antennas are not identical and the antennas' attachment points on the satellite offset from the satellite center-of-gravity plane. Each antenna is modeled as a physical pendulum with two degrees of freedom: in-spin plane and out-of-plane motion. Numerical simulation results for the Geotail satellite are given.

Author

A89-38110

# DYNAMICS OF THE DUAL SPIN TURN

HIROSHI NAGANO (National Space Development Agency of Japan, Tsukuba Space Center, Japan) IN: *International Symposium on Space Technology and Science*, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 627-632.

Copyright

In the initial attitude acquisition of a GEO satellite, the axis around which a bias-momentum satellite spins can be transferred

directly by means of the run-up of a momentum wheel. This technique is called the dual-spin turn. In this paper, the dynamics of the dual-spin turn is formulated, and stability conditions are obtained. Numerical examples show that a nutation occurs as the wheel runs up, and that the nutation angle depends on dynamics parameters. Generally, the larger the spacecraft momentum is and the lower the wheel run-up rate is, the smaller the nutation angle becomes. Author

A89-38111

#### THE DYNAMICS OF SPACECRAFT WITH LIQUID FILLED TANKS AND LARGE FLEXIBLE SOLAR PANELS

NAIGONG ZHANG and LINGLI TANG (Chinese Academy of Sciences, Space Science and Application Research Center, Beijing, People's Republic of China) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 633-638. Copyright

Dynamic coupling in a spacecraft with liquid-filled tanks is studied. The liquid is assumed to be nonviscous, incompressible, nonvortical, and with weak slosh motion. The motion equation of a spacecraft with liquid filled tanks, large flexible solar panels, and a rigid central body are obtained by the theorem of moment of momentum and Lagrange equations; the motion of the elastic solar panels is described by means of the FEM. Author

A89-38112

#### SATELLITE DYNAMICS DURING DEPLOYMENT OF A LARGE FLEXIBLE ANTENNA REFLECTOR

MASAZUMI UEBA (Nippon Telegraph and Telephone Public Corp., Radio Communication Systems Laboratories, Yokosuka, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 639-642. Copyright

This paper describes a simulation of the deployment of two antisymmetric antenna reflectors on the Japanese ETS-VI spacecraft for multibeam satellite communication. Attitude error during deployment and after latch-up, maximum deployment velocity, and impact load by deployment mechanisms were numerically evaluated. Preload and stiffness of the torsion spring at the hinges were selected as parameters. It is concluded that attitude error during deployment is independent of torque sequence, that its magnitude is dominated by whole angular momentum and deployment angle, and that attitude variation after latch-up and impact load are proportional to the energy imparted by the torsion spring. Author

A89-38113

#### TRANSIENT ATTITUDE ANALYSIS OF SATELLITES DURING DEPLOYMENT OF ELASTIC APPENDAGES

YUJI MATSUZAKI (Nagoya University, Japan), TETSUYA HARADA (Kawasaki Heavy Industries, Ltd., Aircraft Engineering Div., Kamagihara, Japan), and KEIICHI KIMURA IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 643-648. Copyright

The attitude dynamics of a spinning satellite with deploying flexible appendages is analyzed, considering both bending and torsional oscillations of the appendages to examine a dynamic interaction between the main rigid body and elastic appendages of the satellite. The effects of system parameters such as the spin rate and moment of inertia of the rigid body and the inertia, stiffness, and deployment rate of the appendages are studied. Equations of motion are obtained using a Lagrangian procedure and are solved numerically using the Gears method with automatic step-size adjustment and built-in error control. Author

A89-38181

#### ATTITUDE CONTROL OF A SPACECRAFT DURING EXTENSION OF FLEXIBLE APPENDAGES

TAKESHI AOKI (Nagoya Municipal Industrial Research Institute, Japan) and HIROBUMI OHTA (Nagoya University, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1159-1164. Copyright

This paper describes attitude dynamics and control of a flexible spacecraft which has a rotor and two reaction wheels inside of the rigid body and four flexible appendages attached outside of it. The effect of disturbances, which occur during extension of flexible appendages, on the attitude behavior is analyzed using the method of multiple scales. The vibration of the flexible appendages has a significant effect on the attitude motion of the spacecraft, which becomes unstable as the length of the appendages increases. However, it is shown that reaction wheels suppress the disturbances and can make the attitude motion stable. Author

A89-38182

#### NUTATION DAMPING FROM LIQUID IN SPHERICAL TANKS

KENT FOLGATE and DANIEL STERN (General Electric Co., Astro-Space Div., Philadelphia, PA) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1165-1174. Copyright

A set of linearized equations has been derived to describe the liquid motion in a fuel tank driven by nutation. The model includes a resonant slosh mode and a nonresonant agitator mode of liquid motion. The model of liquid in one tank is integrated into a total system model to yield a linearized fifth order system. An approximate system time constant formula is obtained to study the cause and effect relationship of the fuel tank and the liquid parameters of the system. An example is presented, using the equations to study a typical set of spacecraft parameters. R.B.

A89-38184

#### POINTING AND MICROGRAVITY TECHNOLOGY FOR SPACE ACTIVITIES IN THE 1990S

YOSHIMARU SHIMAMOTO, HITOSHI SUGIURA, and KEIJI GOMA (Toshiba Corp., Komukai Works, Kawasaki, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1181-1186. Copyright

The development of pointing and microgravity technology for future spacecraft is discussed in relation to spacecraft dynamics and control. Current trends in pointing and microgravity research are reviewed. Consideration is given to the development of actuator hardware for the Engineering Test Satellite 6, including large antenna acquisition tracking and pointing, laser beam accurate pointing, and a vibration isolation system for microgravity research. R.B.

A89-38186

#### ECONOMICAL METHOD OF ORIENTATION OF LARGE ORBITAL STATIONS

V. A. SARYCHEV and IJ. A. SADOV (AN SSSR, Institut Prikladnoi Matematiki, Moscow, USSR) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1193-1198. Copyright

The evolution of a large space station orbit is discussed, using the Salyut-Soyuz orbital complex as an example. Calculations are conducted to describe the effects of the nonpotential aerodynamic torque on the orientation of the system. Also, the rotation of a satellite with a magnetic damper is studied numerically. The evolution of resonance effects are examined, emphasizing peculiarities in the station's orbit caused by secondary resonance effects. R.B.

AB9-38187

**NEW APPROACH TO SPACECRAFT CONTROL SYSTEM RECONFIGURATION**

TORU TANABE (Tokyo, University, Japan) and SHINICHI NAKASUKA (IBM Japan, Research Laboratory, Tokyo) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1199-1204.

Copyright

An autonomous controller design system with learning capability is proposed for use in control system reconfiguration. The system can design the proper controller for given control objects to meet specific control requirements and constraints. The system performs searches directed by heuristics obtained by learning. Case studies testing the system are presented, showing that the system may be applied to complicated objects such as MIMO systems. R.B.

AB9-38193

**STUDY OF A MAGNETICALLY SUSPENDED REACTION WHEEL - MATHEMATICAL MODEL AND EVALUATION**

KEIKEN NINOMIYA, HIROKI YOKOTA (Institute of Space and Astronautical Science, Sagami, Japan), YOSHIOHARU SHIMAMOTO, KATSUHIKO TSUNO, and SATOSHI AKABANE (Toshiba Corp., Komukai Works, Kawasaki, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1237-1242.

Copyright

A model of a flat actively-controlled magnetic bearing wheel is tested. A mathematical model is constructed to represent the suspension and rotor dynamics of the wheel. The characteristics and parameters of the magnetic bearing wheel are outlined. Results are presented from tests of the wheel, including evaluations of precession and nutation frequency, precession and nutation damping, rigidity against the gyro effect, and the rotary damping effect. It is found that the motion of the wheel rotor is well represented by the model. Consideration is given to the possible use of the model in designing and evaluating spacecraft attitude control systems. R.B.

AB9-38211

**CONTROL OF A FLEXIBLE SPACE MANIPULATOR WITH THREE DEGREES OF FREEDOM**

TOSHIO FUKUDA (Tokyo, Science University, Japan) and ATSUSHI ARAKAWA IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1349-1354. refs

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A flexible robotic arm with three degrees of freedom is modeled assuming that the links vibrate both transversely and torsionally and that they do not vibrate longitudinally. Based on these assumptions, the dynamics of the three-degrees-of-freedom flexible robotic arm is derived and represented by a set of coupled modal equations, neglecting nonlinear terms. The state feedback control method is used to suppress the coupled vibrations. Author

AB9-38213

**COLOCATED OUTPUT CONTROL WITH POLE PLACEMENT IN A SPECIFIC REGION**

MOHAMED SAMIR ELBUNI and MINORU HIGASHIGUCHI (Tokyo, University, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1363-1369. refs

Copyright

Closed-loop performance properties of large flexible space structures (LSS) with colocated actuators and sensors is considered. The paper is concerned with finding an output feedback gain matrix that will result in a closed-loop stable system with desired performance qualities. Two design examples for typical LSS representatives are presented, examining the effects of the

output control law on the stability, modal frequencies, and modal damping factors of the closed-loop performance. Author

AB9-38214

**ADAPTIVE CONTROL OF LARGE SPACE STRUCTURES**

YUZO SHIMADA (Nihon University, Funabashi, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1371-1376. refs

Copyright

This paper deals with the application of a model reference adaptive control theory to the attitude control of large space structures that do not satisfy the conditions of sensor/actuator collocation. Signals from several different positions on flexible appendages are combined into outputs so that the number of outputs is the same as the number of inputs. As an example, a spacecraft is considered that has flexible solar paddles and a momentum wheel within the rigid central body. Author

AB9-38215

**SOME NEW METHODS FOR STABILITY ROBUSTNESS ANALYSIS OF ATTITUDE CONTROL SYSTEM OF FLEXIBLE SPACECRAFT**

SHUIE XU, YAOHUA WU (Harbin Institute of Technology, People's Republic of China), and GUANGREN DUAN IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1377-1382. refs

Copyright

In this paper, generalized positive definite matrix is defined. The stability robustness problem of attitude control system of flexible spacecraft is investigated. The uncertainties in the mathematical model of the system caused by the rotation of solar arrays and momentum wheels are described by interval matrices. Some theorems about stability robustness are derived. A numerical example is given. Author

AB9-38216

**FILTER ACCOMMODATED REGULATOR FOR LARGE SPACE STRUCTURES CONTROL AND ITS ROBUSTNESS**

TAKASHI KIDA, ISAO YAMAGUCHI (National Aerospace Laboratory, Chofu, Japan), and MASAO IKEDA (Kobe University, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1383-1388.

Copyright

This paper studies a design method of the filter accommodated LQ regulator for the LSS control. It has the stability robustness against the high-frequency residual modes which are neglected at the controller design phase. The algorithm makes it possible to attain the excellent control performance without causing the spillover instability. Some numerical evaluations are made for a flexible spacecraft model to demonstrate its efficiency. Author

AB9-38382

**THE OPTIMAL LOCATION OF SENSORS AND ACTUATORS FOR ACTIVE VIBRATION SUPPRESSION OF LARGE SPACE STRUCTURES**

KENJI MINESUGI IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 2565-2570.

Copyright

This paper presents an approach to the optimal location of sensors and actuators on large space structures in active suppression of vibration. An analytical index is defined to evaluate their locations quantitatively. This index, called 'system controllability measure', is determined in proportion to the control efficiency, which is a reciprocal of a performance index in the linear quadratic optimal control law. The model is a simple free-free uniform beam. The system controls several modes including rigid modes, translation, and rotation. The least number of sensors and actuators are used and colocated on this model. As the



result of the simulation, it is shown that the effects of initial conditions, rigid modes, and coupling between controlled modes of the same natural frequency have to be taken into account to obtain a useful index in finding an optimal location approximately.

Author

AB9-39520

**EFFECTS OF THE POISSON RATIO AND NEGATIVE THRUST ON THE DYNAMIC STABILITY OF A FREE PLATE SUBJECTED TO A FOLLOWER FORCE**

K. HIGUCHI and E. H. DOWELL (Duke University, Durham, NC) *Journal of Sound and Vibration* (ISSN 0022-460X), vol. 129, March 8, 1989, p. 255-269. refs  
(Contract DAAL03-87-K-0023)

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The macroscopic Poisson ratio of a large plate-like truss structure may vary due to the geometry of the truss. Studied are the effects of the Poisson ratio and negative thrust on the dynamic stability of a flexible rectangular plate which has four free edges. One of the four edges is subjected to a tangential follower thrust. The model is simplified to a continuous isotropic plate, and is investigated by means of modal analysis. A change in Poisson ratio sometimes reduces the flutter load drastically due to a weak flutter instability.

Author

AB9-40458

**DYNAMICAL CONTROL AND DESIGN OF FLEXIBLE STRUCTURES**

M. C. DELFOUR (Montreal, Université, Montreal, Canada) IN: Stabilization of flexible structures; Proceedings of the ComCon Workshop, Montpellier, France, Dec. 11-15, 1987. Los Angeles, CA, Optimization Software, Inc., 1988, p. 62-91. Research supported by the Ministère de l'Éducation du Québec. refs  
(Contract NSERC-A-8730)

Copyright

Recent mathematical developments and new issues in the dynamical design and control of flexible structures are surveyed. The stabilization of a bar in torsion is discussed, and the effect of delays in the feedback loop is considered. The computation of eigenvalues by Kuhn's method is examined. Robustness problems in one-dimensional structures are examined as illustrations.

C.D.

AB9-40467

**ON THE SELF-STABILIZATION OF DAMPED FLEXIBLE STRUCTURES**

R. TEMAM (Paris XI, Université, France) IN: Stabilization of flexible structures; Proceedings of the ComCon Workshop, Montpellier, France, Dec. 11-15, 1987. Los Angeles, CA, Optimization Software, Inc., 1988, p. 273-281. refs

Copyright

Some results concerning the self-stabilization of small-wavelength oscillations in damped flexible structures are described. The spectrum of natural oscillations of the system are decomposed into small and large wavelengths. The equations governing the interactions between these two groups of oscillations are presented, and it is shown that the small-wavelength oscillations tend exponentially fast to a small value without the need of a control mechanism on these modes. The control mechanism is only necessary for a finite number of modes, i.e., the large-wavelength group. This opens the possibility of applying such systems to a method of finite-dimensional control.

C.D.

AB9-40468

**EXISTENCE RESULT FOR THE BALAKRISHNAN ENHANCEMENT OF A FLEXIBLE STRUCTURE WHEN B(ASTERISK) RANGES IN H**

J. P. ZOLESIO (Montpellier II, Université, France) IN: Stabilization of flexible structures; Proceedings of the ComCon Workshop, Montpellier, France, Dec. 11-15, 1987. Los Angeles, CA, Optimization Software, Inc., 1988, p. 295-307. refs

Copyright

The stabilization of flexible structures is studied, finding a nonlinear system where the nonlinear mapping  $f$  is nonlocally

Lipschitzian and nonmonotone. In spite of this lack of good behavior by  $f$ , a global existence result is obtained for mild and strong solutions of the problem posed by Balakrishnan (1987) regarding stability enhancement of flexible structures by nonlinear boundary feedback control.

C.D.

AB9-40916\*# California Univ., Los Angeles.

**ACCURATE CALCULATION OF CONTROL-AUGMENTED STRUCTURAL EIGENVALUE SENSITIVITIES USING REDUCED-ORDER MODELS**

ELI LIVNE (California, University, Los Angeles) *AIAA Journal* (ISSN 0001-1452), vol. 27, July 1989, p. 947-954. refs  
(Contract NSG-1490)

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A method is presented for generating mode shapes for model order reduction in a way that leads to accurate calculation of eigenvalue derivatives and eigenvalues for a class of control augmented structures. The method is based on treating degrees of freedom where control forces act or masses are changed in a manner analogous to that used for boundary degrees of freedom in component mode synthesis. It is especially suited for structures controlled by a small number of actuators and/or tuned by a small number of concentrated masses whose positions are predetermined. A control augmented multispan beam with closely spaced natural frequencies is used for numerical experimentation. A comparison with reduced-order eigenvalue sensitivity calculations based on the normal modes of the structure shows that the method presented produces significant improvements in accuracy.

Author

AB9-43025\* Catholic Univ. of America, Washington, DC.

**MODIFIED INDEPENDENT MODAL SPACE CONTROL METHOD FOR ACTIVE CONTROL OF FLEXIBLE SYSTEMS**

A. BAZ, S. POH (Catholic University of America, Washington, DC), and P. STUDER (NASA, Goddard Space Flight Center, Greenbelt, MD) *Institution of Mechanical Engineers, Proceedings, Part C - Journal of Mechanical Engineering Science* (ISSN 0954-4062), vol. 203, no. C2, 1989, p. 103-112. Previously announced in STAR as N87-23980. refs

(Contract NAG5-520; NAG5-749)

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A modified independent modal space control (MIMSC) method is developed for designing active vibration control systems for large flexible structures. The method accounts for the interaction between the controlled and residual modes. It incorporates also optimal placement procedures for selecting the optimal locations of the actuators in the structure in order to minimize the structural vibrations as well as the actuation energy. The MIMSC method relies on an important feature which is based on time sharing of a small number of actuators, in the modal space, to control effectively a large number of modes. Numerical examples are presented to illustrate the application of the method to generic flexible systems. The results obtained suggest the potential of the devised method in designing efficient active control systems for large flexible structures.

Author

AB9-43045#

**COMPARISON OF A FUZZY LOGIC CONTROLLER WITH A P + D CONTROL LAW**

S. DALEY (Brunel University, Uxbridge, England) and K. F. GILL (Leeds, University, England) *ASME, Transactions, Journal of Dynamic Systems, Measurement, and Control* (ISSN 0022-0434), vol. 111, June 1989, p. 126-137. refs

Copyright

A study is described that compares the performance of a self-organizing fuzzy logic control law (SOL) with that of the more traditional P + D algorithm. The multivariable problem used for the investigation is the attitude control of a flexible satellite that has significant dynamic coupling of the axes. It is demonstrated that the SOL can provide good control, requires limited process knowledge and compares favorably with the P + D algorithm.

Author

ABR-43133

**CONTROL OF A SPACECRAFT USING A REACTION CONTROL SYSTEM**

JOHN D. FOLEY (Martin Marietta Corp., Denver, CO) IN: 1988 Annual Summer Computer Simulation Conference, 20th, Seattle, WA, July 25-28, 1988, Proceedings. San Diego, CA, Society for Computer Simulation International, 1988, p. 235-240. Copyright

A model describing the dynamics of a reaction control system is presented. The simulation incorporated effects such as time delays, hysteresis, and external disturbances to the spacecraft. The simulation revealed that the width of the deadband completely dictates the pointing accuracy of the spacecraft. Higher pointing accuracy requirements increase the amount of fuel consumed since there are more thruster firings for a smaller deadband. K.K.

ABR-43148

**STRUCTURES/CONTROLS ANALYSIS OF A VERSATILE VIBRATION ISOLATOR**

JAMES W. JETER and RICHARD D. BALDWIN (Hughes Aircraft Co., Albuquerque, NM) IN: 1988 Annual Summer Computer Simulation Conference, 20th, Seattle, WA, July 25-28, 1988, Proceedings. San Diego, CA, Society for Computer Simulation International, 1988, p. 861-869. (Contract F29601-85-C-0133) Copyright

A six degree of freedom isolation/repositioning system composed of linear actuators provides unusual potential for application to space systems. Inherent to such a system and its requirements are such concerns as bidirectional isolation, articulation capability, and cross coupling between linear actuators. These concerns and the space application produce requirements and constraints on the modeling and analysis of such a system. This paper discusses the complications which develop in the structures/controls modeling process and the approaches used to deal with them. Author

ABR-43153

**TREETOPS - MULTI-FLEX-BODY SOFTWARE APPLIED TO AN SDI SLEW ACTUATOR STUDY**

H. C. GELDERLOOS and K. W. LIPS (Honeywell, Inc., Space and Strategic Avionics Div., Clearwater, FL) IN: 1988 Annual Summer Computer Simulation Conference, 20th, Seattle, WA, July 25-28, 1988, Proceedings. San Diego, CA, Society for Computer Simulation International, 1988, p. 948-954. refs Copyright

The current status of the generic multibody dynamics/controls simulation software known as TREETOPS is reviewed. A brief assessment is given vis a vis the alternative DISCOS code. In particular, the significance of the geometric nonlinearity referred to as foreshortening is examined for space applications and found not to be a factor in TREETOPS applications to date. TREETOPS is then used to generate a linear 3-body system model (including modal frequencies and modal shapes) for an SDI Ground Based Laser (GBL) fighting mirror structure. This model is validated by comparing with NASTRAN-only system results. The correlation is quite good, justifying extension of the model to include detailed sensor and actuator capability which, in turn, allows for controls design. Author

ABR-45057\* Ohio State Univ., Columbus.

**ROBUST CONTROL DESIGN FOR AEROSPACE APPLICATIONS**

RAMA K. YEDAVA'LI (Ohio State University, Columbus) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251), vol. 25, May 1989, p. 314-324. refs (Contract NAG1-578; F33615-84-K-3606) Copyright

Time-domain control design for stability robustness of linear systems with structured uncertainty is addressed. Upper bounds on the linear perturbation of an asymptotically stable linear system are obtained, making it possible to maintain stability by using the structural information of the uncertainty. A quantitative measure

called the stability robustness index is introduced and used to design controllers for robust stability. The proposed state feedback control design algorithm can be used, for a given set of perturbations, to select the range of control effort for which the system is stability-robust. Conversely it can be used, for a given control effort, to determine the size of the tolerable perturbation. The algorithm is illustrated with examples from aircraft control and large-space-structure control problems. I.E.

ABR-45788

**THE PLANAR TRUSS - AN ACTIVE CONTROL TEST BED**

STEVEN E. LAMBERSON (U.S. Air Force Academy, Colorado Springs, CO) and WILLIAM L. HALLAUER (USAF, Frank J. Seiler Research Laboratory, Colorado Springs, CO) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 774-782. Copyright

A twenty-bay planar truss is being developed for use as a control methodology test bed. Plans for using the truss include studies of the relative effectiveness of actuation mechanisms such as force links which push or pull against adjacent portions of the structure, airjets, and reaction inertia actuators. The analytical models of the truss were calibrated with a six-bay portion of the proposed structure. The truss components and frequency response functions are examined. The tests on the six-bay truss are used to make vibration control predictions for the twenty-bay truss. R.B.

ABR-48119

**CONVEX ANALYSIS AND GLOBAL OPTIMIZATION OF JOINT ACTUATOR LOCATION AND CONTROL PROBLEMS**

JOSE C. GEROMEL (Campinas, Universidade Estadual, Brazil) IEEE Transactions on Automatic Control (ISSN 0018-9286), vol. 34, July 1989, p. 711-720. Research supported by FAPESP and CNR. refs Copyright

It is shown that the optimal value of the continuous-time linear-quadratic problem regarded as a function of the system model and index parameters exhibits properties (convexity, concavity, and monotonicity) especially suitable for optimization purposes. Based on this fact, a procedure for the global solution of eventually nonconvex problems involving this function is proposed. Such problems embody some known designs, such as filtering under noise uncertainty or precision constraints and optimal actuator/sensor location. The last problem is deeply analyzed, and two practical applications (control of satellite attitude and control of large flexible systems) are included. I.E.

ABR-51712#

**REPRESENTATION OF CONTROL SYSTEMS FOR PRELIMINARY SPACE STATION DESIGN**

PAUL BLELLOCH (SDRC, Inc., San Diego, CA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Sept.-Oct. 1989, p. 709-713. Previously cited in issue 22, p. 3550. Accession no. A87-50486. refs Copyright

ABR-51713\*# Texas Univ., Austin.

**NEW APPROACH TO ATTITUDE/MOMENTUM CONTROL FOR THE SPACE STATION**

B. WIE, K. W. BYUN, V. W. WARREN (Texas University, Austin), D. GELLER, D. LONG, and J. SUNKEL (NASA, Johnson Space Center, Houston, TX) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Sept.-Oct. 1989, p. 714-722. Previously cited in issue 21, p. 3509. Accession no. A88-50233. refs Copyright

ABR-51714#

**OPTIMAL CONTROL OF LARGE SPACE STRUCTURES USING DISTRIBUTED GYRICITY**

G. M. T. D'ELEUTERIO (Toronto, University, Downsview, Canada) and C. J. DAMAREN (Dynamics and control of large structures;

Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987, p. 407-422. *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090), vol. 12, Sept.-Oct. 1989, p. 723-731. Research supported by NSERC. Previously cited in issue 02, p. 203, Accession no. A89-11677. refs  
Copyright

## A89-52531#

## ROBUST COMPENSATOR DESIGN VIA CONTROL AND OBSERVATION NORMALIZATION

JOHN R. SESAK and KRISTIN M. STRONG (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 1, Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 46-54. refs  
(AIAA PAPER 89-3431) Copyright

This paper considers the problem of robust compensator design for optimal control and estimation systems, and presents a new method for LQG compensator design using structured control and observation constraints. These constraints tend to normalize the control and observation effort, providing indirect control over the compensator poles and bandwidth. An example derived from flexible spacecraft control illustrates the procedure. Author

## A89-52533\*# Texas Univ., Austin.

## PULSE MODULATED CONTROL SYNTHESIS FOR A FLEXIBLE SPACECRAFT

TOBIN C. ANTHONY, BONG WIE (Texas, University, Austin), and STANLEY CARROLL (NASA, Marshall Space Flight Center, Huntsville, AL) IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 1, Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 65-76. refs  
(Contract NAS8-36224)  
(AIAA PAPER 89-3433) Copyright

The describing function method is employed for the nonlinear control analysis and design of a flexible spacecraft equipped with pulse modulated reaction jets. The method provides a means of characterizing the pulse modulator in terms of its gain and phase for structural mode limit cycle analysis. Although the describing function method is inherently inexact and is not widely used in practice, a new way of utilizing it for practical control design problems is presented. It is shown that the approximations inherent in the method can be accounted as a modeling uncertainty for the nonlinear control robustness analysis. The pulse modulated control system of the Intelsat 5 spacecraft is used as an example to illustrate the concept and methodology developed in the paper. The nonlinear stability margins predicted by the describing function analysis are verified from nonlinear simulations. Author

## A89-52534#

## AN OPTIMAL PROJECTION CONTROLLER FOR AN EXPERIMENTAL TRUSS STRUCTURE

LEE D. PETERSON (Sandia National Laboratories, Albuquerque, NM) IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 1, Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 77-88. refs  
(Contract DE-AC04-76DP-00789)  
(AIAA PAPER 89-3434) Copyright

Optimal Projection (OP) reduced order control theory is applied experimentally to a controlled structure testbed. The test structure has twenty-five disturbed modes, and the controller uses four strain sensors to command four noncollocated stress actuators. The best OP design, an 18th order controller derived from a 58th order structural model, is experimentally found to reduce the broadband vibration of five independent pointing error measures by as much as 66 percent without saturating the actuators and without destabilizing high frequency modes. A similar reduced order Linear Quadratic Gaussian (LQG) controller is found to always destabilize high frequency modes. The homotopy algorithm used to solve the OP synthesis equations is described, and its convergence is discussed. Analytical and experimental closed-loop performance

for a series of OP and LQG controllers are compared to illustrate the effect of structural dynamic modeling errors on the results.

Author

## A89-52535#

## PASSIVE CONTROL OF ALTERNATIVE ASSEMBLY CONFIGURATIONS OF SPACE STATION FREEDOM

JAMES W. WADE (Lockheed Engineering and Sciences Co., Houston, TX) IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 1, Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 89-96. refs  
(AIAA PAPER 89-3435) Copyright

The use of a spherical passive magnetic damper (PMD) to improve the stability and controllability of the flight-1 configuration of the International Space Station is discussed. The flight-1 configuration (F1C) in effect in November 1988 includes the assembly work platform (AWP), starboard alpha joint, starboard photovoltaic module, reaction-control system (RCS), and a temporary avionics pallet; the drawbacks of the proposed RCS-based attitude control are indicated. Detailed analytical and numerical computations are presented for three alternative F1Cs in which attitude control is achieved using a PMD. It is shown that good control could be obtained using a 10-N-m-sec PMD of reasonable size with either (1) the same components as in the November 1988 F1C, but with the solar array and radiator unextended, or (2) an F1C consisting of two resource nodes; an F1C similar to (1), but with only the solar arrays stowed, would require a too-large 300-N-m-sec PMD. T.K.

## A89-52536\*# Massachusetts Inst. of Tech., Cambridge.

## EXPERIMENTAL INVESTIGATION INTO PASSIVE DAMPING ENHANCEMENT FOR SPACE STRUCTURES

NESBITT W. HAGOOD and EDWARD F. CRAWLEY (MIT, Cambridge, MA) IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 1, Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 97-109. refs  
(Contract NAGW-21)  
(AIAA PAPER 89-3436) Copyright

This work presents experiments which were conducted to verify kinetic and strain energy damping enhancement schemes for large/precision space structures. Two types of damping mechanisms were applied to a 5 meter long, 10 bay aluminum box truss with a quasi free-free three-dimensional suspension. Tuneable proof mass dampers (PMDs) were implemented with space realizable linear electromechanical drivers. Tuneable piezoelectric truss members were designed and constructed for the demonstration of resonant shunted piezoelectric damping concepts. The truss damping was measured and compared to analytical predictions obtained from a frequency domain system modeling technique. The proof mass damper implementation was found to increase first mode damping from 0.6 percent of critical to 6.4 percent of critical with a system mass increase of 2.7 percent. The resonant shunted piezoelectrics increased first mode damping to 6.0 percent with a similar mass penalty. Author

## A89-52556#

## ROBUST FIXED ORDER DYNAMIC COMPENSATION

ANTHONY J. CALISE and EDWARD V. BYRNS, JR. (Georgia Institute of Technology, Atlanta) IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 1, Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 289-295. Research supported by General Electric Co. refs  
(AIAA PAPER 89-3458) Copyright

This paper presents a simple formulation for designing fixed-order dynamic compensators which are robust to both uncertainty at the plant input and structured uncertainty in the plant dynamics. The formulation avoids the introduction of sensitivity states, which has led to complex formulations in earlier studies where only structured uncertainty has been considered.



The usefulness of the design approach is illustrated by an example for high bandwidth control of a flexible spacecraft. Author

#### AB9-52566\*

##### ADAPTIVE CONTROL APPLIED TO MOMENTUM UNLOADING UTILIZING THE LOW EARTH ORBITAL ENVIRONMENT

T. F. BURNS (TRW, Inc., TRW Space and Technology Group, Redondo Beach, CA) and H. FLASHNER (Southern California University, Los Angeles, CA) IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 391-401. refs (AIAA PAPER 89-3472) Copyright

An adaptive control technique for the unloading of spacecraft angular momentum is presented. The technique employs model reference adaptive control theory with Liapunov stability analysis to synthesize a controller utilizing multiple environmental sources in combination for unloading. Simulation studies are presented which employ magnetic, gravity gradient, and aerodynamic torques in a three-way controller. It is shown that momentum is contained within a dead zone introduced for disturbance compensation which is well below reasonable reaction wheel saturation limits for two model spacecraft of much different mass properties. Author

#### AB9-52567\*# National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, TX.

##### AN OPTIMAL MOMENTUM MANAGEMENT CONTROLLER FOR THE SPACE STATION

J. W. SUNKEL (NASA, Johnson Space Center, Houston, TX) and L. S. SHIEH (Houston, University, TX) IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 402-411. refs (Contract DAAL03-87-K-0001; NAG9-211) (AIAA PAPER 89-3473) Copyright

This paper presents a new sequential design procedure for determining an optimal CMG (control moment gyro) momentum management and attitude control system for the Space Station Freedom. First, the Space Station equations of motion are linearized and uncoupled, and the associated state space equations are defined. Next, a new sequential procedure is used for the development of a continuous quadratic regulator with eigenvalue placement in a specified region of the complex plane. The regional pole assignment method is utilized since it is best suited for tradeoffs between eigenvalue locations and robustness with respect to parameter variations, sensor failures, implementation accuracies and gain reductions. The matrix sign function is used for solving the Riccati equations which appear in the design procedure. Simulation results are given which show that the resultant design provides desired system performance. Author

#### AB9-52568\*# National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, TX.

##### DIGITAL REDESIGN OF AN OPTIMAL MOMENTUM MANAGEMENT CONTROLLER FOR THE SPACE STATION

J. W. SUNKEL (NASA, Johnson Space Center, Houston, TX) and L. S. SHIEH (Houston, University, TX) IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 412-421. refs (Contract DAAL03-87-K-0001; NAG9-211) (AIAA PAPER 89-3474) Copyright

A new digital redesign technique is developed for determining the digital version of an optimal momentum management controller previously designed by the authors for the Space Station Freedom. The technique matches all the states at all sampling instants to find a pseudo-continuous time quadratic regulator. It is shown that the redesigned digital states closely match the continuous time optimal states. It is also shown how the redesign technique can be applied to a state estimator. Author

#### AB9-52570\*# Texas Univ., Austin.

##### PERIODIC-DISTURBANCE ACCOMMODATING CONTROL OF THE SPACE STATION FOR ASYMPTOTIC MOMENTUM MANAGEMENT

WAYNE WARREN, BONG WIE (Texas, University, Austin), and DAVID GELLER (NASA, Johnson Space Center, Houston, TX) IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 431-442. refs (AIAA PAPER 89-3476) Copyright

Periodic-disturbance accommodating control is investigated for asymptotic momentum management of control moment gyros used as primary actuating devices for the Space Station. The proposed controller utilizes the concepts of quaternion feedback control and periodic-disturbance accommodation to achieve oscillations about the constant torque equilibrium attitude, while minimizing the control effort required. Three-axis coupled equations of motion, written in terms of quaternions, are derived for roll/yaw controller design and stability analysis. The quaternion feedback controller designed using the linear-quadratic regulator synthesis technique is shown to be robust for a wide range of pitch angles. It is also shown that the proposed controller tunes the open-loop unstable vehicle to a stable oscillatory motion which minimizes the control effort needed for steady-state operations. Author

#### AB9-52571\*

##### PREFERRED GIMBAL ANGLES FOR SINGLE GIMBAL CONTROL MOMENT GYROS

S. R. VADALI, H.-S. OH, and S. R. WALKER (Texas A & M University, College Station) IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 443-452. Research supported by the Texas Advanced Research and Technology Program. refs (AIAA PAPER 89-3477) Copyright

The paper is concerned with the problem of determining preferred initial gimbal angles for single-gimbal control moment gyro (SCMG) systems to avoid internal singularities. A simple procedure for determining the preferred initial gimbal angles is demonstrated which can be applied to any number of control moment gyros in a cluster. Several examples are presented, including active momentum management and attitude control of a space station. It is shown that singularities can be easily avoided by selecting proper initial gimbal angles. A feedback scheme for positioning the gimbals is also discussed. V.L.

#### AB9-52586\*# Texas Univ., Austin.

##### A NEW ADAPTIVE CONTROL APPROACH FOR AEROSPACE VEHICLES WITH PARAMETER UNCERTAINTIES

YUNGSUN HAHN and JASON L. SPEYER (Texas, University, Austin) IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 583-592. refs (Contract NAG9-288) (AIAA PAPER 89-3494) Copyright

A new stochastic adaptive control structure is developed for the problem of combined parameter estimation and control of aerospace vehicles with changing parameters. Parameter uncertainties are modeled as first-order Gauss-Markov processes, and are introduced to the system dynamics through a small parameter. It is assumed that an accurate inertial measurement unit gives perfect measurements of the state variables. Since the stochastic system is assumed to be Gauss-Markov, the density function of the parameters given these measurements is conditionally Gaussian. Based on this conditionally Gaussian density, the problem of minimizing a quadratic cost over an infinite time horizon can be set up within the framework of stochastic optimal control theory. The optimal feedback control law is derived from a straightforward expansion of the Hamilton-Jacobi-Bellman equation, based on the LQG solution. The resulting nonlinear

controller is applied to the pitch axis control of a space platform with uncertain moments of inertia and is shown to produce marked improvement over a fixed controller. Author

#### AB9-52606#

**MULTI-BODY INTERACTION EFFECTS ON SPACE STATION ATTITUDE CONTROL AND MOMENTUM MANAGEMENT**  
BONG WIE (Texas University, Austin), ANREN HU, and RAMENDRA SINGH (Dynacs Engineering Co., Inc., Clearwater, FL) IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 1, Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 770-780. refs (AIAA PAPER 89-3514) Copyright

The effects of multi-body dynamic interaction on attitude control and momentum management of the Space Station Freedom are investigated with emphasis on the impact of the Mobile Remote Manipulator System and Mobile Transporter operations. In particular, the performance and stability of both classical and modern controllers are evaluated by nonlinear simulations of a rigid, two-body vehicle with prescribed motion of the second body relative to the core body. It is shown that the Mobile Transporter maneuver with a large payload can affect the overall system response significantly and in certain cases the Space Station control system can become unstable. The instability, caused by more than 30 percent changes in the overall inertia property, indicates a need for an adaptive control or gain scheduling for the large payload maneuvers. Author

#### AB9-52620#

**ADAPTIVE CONTROL OF FLEXIBLE STRUCTURES USING SELF TUNING DIGITAL NOTCH FILTERS**  
W. P. MAGGARD (Control Dynamics Co., Huntsville, AL), J. R. MITCHELL, and R. D. IRWIN (Ohio University, Athens) IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 2, Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 911-920. refs (AIAA PAPER 89-3532) Copyright

An adaptive control scheme for suppressing vibrations of large flexible structures is presented. The control scheme utilizes self-tuning digital notch filters to minimize the excitation of the system resonant modes by control forces. The notch filters are tuned such that their center frequencies coincide with the system resonant frequencies, which are identified using an FFT (Fast Fourier Transform) and a heuristic search technique. This enables the control system to automatically adapt to variations or uncertainties in the dynamical characteristics of the plant. The control scheme is evaluated by means of a hardware-in-the-loop simulation using an analog computer to solve the plant equations of motion in real time. The resonant frequency detection and control functions are implemented in real time using commercially available signal analysis and digital control hardware. Conclusions regarding the performance, advantages, and limitations of this adaptive control scheme are presented along with recommendations for further research and development. Author

#### AB9-52622#

**ROBUSTNESS WITH POSITIVE REAL CONTROLLERS FOR LARGE SPACE STRUCTURES**  
G. L. SLATER, Q. ZHANG, and A. BOSSE (Cincinnati, University, OH) IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 2, Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 932-941. Research sponsored by USAF. refs (AIAA PAPER 89-3534) Copyright

The robustness of a continuous positive real controller design is established by linking the positivity theory to the standard singular value robustness tests. By application of the singular value test to a model of the deviation from positivity induced by actuators, computational delays, etc., the global stability of the control design can be assured, even with significant modeling errors due to model

uncertainty. Both theoretical and experimental verification of this stability result is presented. Author

#### AB9-52623#

#### ROBUST LSS CONTROLLER DESIGN BY FREQUENCY SHAPING

T. KIDA (National Aerospace Laboratory, Chofu, Japan), M. IKEDA (Kobe University, Japan), and Y. TSUBOKAWA IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 2, Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 942-948. refs (AIAA PAPER 89-3535) Copyright

This paper proposes to give the low-pass property to the LQ regulator in order to enhance the LSS stability robustness against the residual modes. The controller is designed in a frequency-shaped regulator framework. Its characteristics are discussed. Then the construction of output feedback controller is considered to preserve the frequency-shaped loop transfer property of the regulator. Three types of design procedures are studied and compared with each other for an LSS example. Author

#### AB9-52624#

#### SELF-BALANCED ACTIVE MODAL DAMPING FOR FLEXIBLE SPACECRAFT USING THRUSTERS AND BANDPASS FILTERS

HARI B. HABLANI and JAMES C. JANSZ (Rockwell International Corp., Seal Beach, CA) IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 2, Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 949-953. refs (AIAA PAPER 89-3536) Copyright

A self-balanced active modal damping scheme is developed for elastic modes of free space structures using thrusters, gyros, and bandpass filters (self-balanced because it results in no net change in spacecraft attitude). This scheme is necessarily open-loop because a bandpass filter, whether ideal or minimum-rise-time, may not have enough bandwidth to track an actively damped mode. Modeling uncertainties pose no problem because the minimum-rise-time filter can determine the modal frequency accurately, and the errors in modal coefficients and damping can be compensated for with vernier thrusters. The scheme is illustrated on a generic spacecraft whose first symmetric transverse bending mode (0.28 Hz) and the first in-plane antisymmetric bending mode (0.97 Hz) are both actively damped to a few thousandths of their initial amplitudes. Author

#### AB9-52634#

#### USE OF INTERMITTENT MANEUVERS FOR MISS DISTANCE REDUCTION IN EXOATMOSPHERIC ENGAGEMENTS

MILJEA TAJIK (Integrated Systems, Inc., Santa Clara, CA) and JASON L. SPEYER (Texas University, Austin) IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 2, Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1041-1047. refs (AIAA PAPER 89-3547) Copyright

For exoatmospheric missile engagements, direct application of conventional guidance laws may result in unacceptable miss distances because of the poor observability associated with angles-only measurements and homing geometry. A trajectory modulation method called intermittent maneuvering is proposed to enhance observability and reduce miss distance. An estimation algorithm called modified-gain pseudomeasurement filter is also proposed for the tracking filter design. Statistical simulations involving realistic interceptor and target systems as well as filter/guidance algorithms are conducted to demonstrate the significant performance improvements produced by the use of intermittent maneuvers. Author

#### AB9-52654\*#

Jet Propulsion Lab., California Inst. of Tech., Pasadena.

#### EXPERIMENTS IN MULTIVARIABLE ADAPTIVE CONTROL OF A LARGE FLEXIBLE STRUCTURE

C.-H. C. H. D. S. BAYARD, A. AHMED, and S. J. WANG (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN:

AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 2, Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1207-1217. Research supported by USAF. refs  
(AIAA PAFJR 89-3571) Copyright

A six-input/six-output multivariable adaptive controller is used to control a large 3-dimensional flexible structure experiment. For this purpose, the JPL/AFAL antenna-like experiment structure is used, with instrumentation distributed on both the hub and the ribs. This represents a significant increase in complexity relative to earlier adaptive control experiments performed on the same structure, utilizing a two-input/two-output set-up with instrumentation on the hub alone. The increase in instrumentation significantly increases spatial controllability, and excitation and control of a much larger set of modes. This paper documents multivariable adaptive control experiments on this structural configuration, and discusses many of the associated design and implementation issues required for successful operation. Author

**ABR-53922#**

**SELECTION OF DYNAMIC SENSORS AND ACTUATORS IN THE CONTROL OF LINEAR SYSTEMS**

G. A. NORRIS and R. E. SKELTON (Purdue University, West Lafayette, IN) ASME, Transactions, Journal of Dynamic Systems, Measurement, and Control (ISSN 0022-0434), vol. 111, Sept. 1989, p. 389-397. refs  
Copyright

This paper selects sensors and actuators (location, type, and number) from an admissible set. An approximate solution to this integer programming problem is sought. Given the optimal use of the entire admissible set of sensors and actuators, it is possible to decompose the quadratic cost function into contributions from each stochastic input and each weighted output. In the past, these suboptimal cost decomposition methods of sensor and actuator selection have been used to locate perfect (infinite bandwidth) sensors and actuators on large scale systems. This paper extends these ideas to the more practical case of imperfect actuators and sensors with dynamics of their own. Secondly, the old cost decomposition methods are discarded for improved formulas for sensor and actuator deletion (from the admissible set). These results show that there exists an optimal number of actuators. Preliminary attempts to solve this new research question are described. It is also shown that there exists optimal dynamics of the actuators. NASA's SCOLE example demonstrates the concepts. Author

**ABR-53936#** Virginia Polytechnic Inst. and State Univ., Blacksburg.

**OPTIMAL LOCATION OF ACTUATORS FOR CORRECTING DISTORTIONS IN LARGE TRUSS STRUCTURES**

RICARDO A. BURDISO and RAPHAEL T. HAFTKA (Virginia Polytechnic Institute and State University, Blacksburg) (Dynamics and control on large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987, p. 323-342) AIAA Journal (ISSN 0001-1452), vol. 27, Oct. 1989, p. 1406-1411. Previously cited in issue 02, p. 203, Accession no. ABR-11672. refs  
(Contract NAG1-224)  
Copyright

**ABR-53942#** Virginia Polytechnic Inst. and State Univ., Blacksburg.

**SENSITIVITY OF ACTIVELY DAMPED STRUCTURES TO IMPERFECTIONS AND MODELING ERRORS**

RAPHAEL T. HAFTKA and RAKESH K. KAPANIA (Virginia Polytechnic Institute and State University, Blacksburg) AIAA Journal (ISSN 0001-1452), vol. 27, Oct. 1989, p. 1434-1440. refs  
(Contract NAG1-224)  
Copyright

The sensitivity of actively damped response of structures with respect to errors in the structural modeling is studied. Two ways of representing errors are considered. The first approach assumes

errors in the form of spatial variations (or imperfections) in the assumed mass and stiffness properties of the structures. The second approach assumes errors due to such factors as unknown joint stiffnesses, discretization errors, and nonlinearities. These errors are represented here as discrepancies between experimental and analytical mode shapes and frequencies. The actively damped system considered here is a direct-rate feedback regulator based on a number of collocated velocity sensors and force actuators. The response of the controlled structure is characterized by the eigenvalues of the closed-loop system. The effects of the modeling errors are thus presented as the sensitivity of the eigenvalues of the closed-loop system. Results are presented for two examples: (1) a three-span simply supported beam controlled by three sensors and actuators, and (2) a laboratory structure consisting of a cruciform beam supported by cables. Author

**ABR-53951**

**1989 AMERICAN CONTROL CONFERENCE, 8TH, PITTSBURGH, PA, JUNE 21-23, 1989, PROCEEDINGS, VOLUMES 1, 2, & 3**

Conference sponsored by the American Automatic Control Council, New York, Institute of Electrical and Electronics Engineers, 1989, p. Vol. 1, 1017 p.; vol. 2, 831 p.; vol. 3, 1029 p. For individual items see ABR-53952 to ABR-54007, ABR-54009 to ABR-54117. Copyright

Papers are presented on such topics as the robust control of robotic manipulators, aircraft control, intelligent control systems, computer networking for real-time control, robust adaptive control, and nonlinear process control. Consideration is also given to advances in distributed detection, control issues for large flexible manipulators, aerospace guidance and control, optimization in biochemical engineering, advanced robotics, fuzzy logic and process control, vibration control, and special architectures in real-time control systems. B.J.

**ABR-53953**

**ROBUSTNESS INVESTIGATION OF ADAPTIVE CONTROL UNDER REFERENCE MODEL SWITCHING FOR A CYLINDRICAL ROBOT**

A. KARIM, G. K. F. LEE, G. R. WIDMANN, and E. M. NEBOT (Colorado State University, Fort Collins) IN: 1989 American Control Conference, 8th, Pittsburgh, PA, June 21-23, 1989, Proceedings, Volume 1, New York, Institute of Electrical and Electronics Engineers, 1989, p. 31-36. Research supported by Martin Marietta Corp. refs  
Copyright

The authors have conducted an investigation into the robustness properties of a robot control strategy based on the direct model reference adaptive control algorithm under switching of the reference model. Experimental results of the investigation are presented for a three-degree-of-freedom cylindrical robot. The control scheme is demonstrated to be a powerful approach to the difficult problems encountered in space robotics control. I.E.

**ABR-53953**

**ACTIVE VIBRATION DAMPING IN BEAMS**

P. HAGEDORN, J. WALLASCHKE, and P. CHEN (Darmstadt, Technische Hochschule, Federal Republic of Germany) IN: 1989 American Control Conference, 8th, Pittsburgh, PA, June 21-23, 1989, Proceedings, Volume 1, New York, Institute of Electrical and Electronics Engineers, 1989, p. 206-211. refs  
Copyright

The traveling-wave approach is discussed for the active vibration control of beams. An active vibration control scheme for the Timoshenko beam is designed using external control forces. Vibration control by means of internal forces, i.e., force systems forming equilibrium groups, is discussed. An unexpected resonance phenomenon occurring in this approach is explained. I.E.



AB9-53985

**AN ACTIVE VIBRATION TUNING METHODOLOGY FOR SMART FLEXIBLE STRUCTURES INCORPORATING ELECTRO-RHEOLOGICAL FLUIDS - A PROOF-OF-CONCEPT INVESTIGATION**

S. B. CHOI, M. V. GANDHI, and B. S. THOMPSON (Michigan State University, East Lansing) IN: 1989 American Control Conference, 8th, Pittsburgh, PA, June 21-23, 1989, Proceedings, Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 694-699. Research supported by the Department of Commerce of the State of Michigan, Research Excellence and Economic Development Fund. refs (Contract DAAL03-88-K-0163)

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Electrorheological fluids undergo a pseudo-phase-change when subjected to an applied electrical potential, and this versatile phenomenon permits the global stiffness and damping properties of the smart structure to be tailored in order to synthesize the desired elastodynamic response. The coupling of this capability with sensors and microprocessors provides the essential ingredients for a class of intelligent materials. A combined theoretical and experimental proof-of-concept investigation on this class of materials is presented by examining the elastodynamic response of cantilevered beam specimens. I.E.

AB9-53986

**CRITICAL ACTIVE DAMPING CONTROL OF A FLEXIBLE SLENDER PLATE USING A DISTRIBUTED MODAL ACTUATOR AND SENSOR**

WEN-WEI CHIANG and CHIH-KUNG LEE (IBM Almaden Research Center, San Jose, CA) IN: 1989 American Control Conference, 8th, Pittsburgh, PA, June 21-23, 1989, Proceedings, Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 700-705. refs

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Active damping control of the structural vibration of a one-dimensional cantilever plate is analyzed and tested. The control algorithm uses rate feedback without using any element tuned to the structural vibration frequencies, so that the sensitivity of the closed-loop stability and performance to resonant frequency variations is minimized. Poly(vinylidene fluoride) layers were attached to all sides of three steel plates to act as distributed actuators and sensors. Both all-mode and single-mode actuator/sensor pairs were designed and studied, and experimental results showed that critical active damping control for the first mode was achieved. The importance of having a distributed modal actuator/sensor for the active damping control of a flexible structure is established. I.E.

AB9-54000

**ROBUST ALGORITHMS FOR CONTROL AND SURVIVABILITY ENHANCEMENT OF SPACE PLATFORMS**

JAMES V. CARROLL and JOHN P. GARNER (Computational Engineering, Inc., Laurel, MD) IN: 1989 American Control Conference, 8th, Pittsburgh, PA, June 21-23, 1989, Proceedings, Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 944, 945. Research supported by SDIO and DNA.

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The need is demonstrated for providing robust control system reconfiguration by showing how failures of sensor and actuator components can degrade the control system performance and lead in many cases to closed-loop instability without reconfiguration. The key elements of a space platform control reconfiguration system are identified and discussed. The concept is simulated on a simple structural model to demonstrate the principles related to reconfiguration control system design and its impact on system performance. A fault-detection logic based on likelihood ratio techniques is implemented for detection and isolation of sensor and actuator failures. State estimation using full-state and reduced-state observers is discussed and a full-state observer is implemented in the simulations. Onboard control system reconfiguration schemes are discussed for the implementation of

discrete linear quadratic Gaussian control. The performance of the integrated reconfiguration system is demonstrated to be superior to that of robust systems without reconfiguration capabilities. I.E.

AB9-54007

**FAULT-TOLERANT SENSOR AND ACTUATOR SELECTION FOR CONTROL OF FLEXIBLE STRUCTURES**

WILLIAM N. MCCASLAND (USAF, Washington, DC) IN: 1989 American Control Conference, 8th, Pittsburgh, PA, June 21-23, 1989, Proceedings, Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 1111-1116. refs

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Consideration is given to sensor and actuator placement for structural control with the possibility of failures. Norms on controllability or observability gramians are selected as a performance measure and algorithms are developed. Scaling of the state space is based on selection of a throughput path. Examples are shown for a simply supported beam and a large-scale finite-element model. I.E.

AB9-54010\* Illinois Univ., Urbana.

**BANDWIDTH-LIMITED ROBUST NONLINEAR SLIDING CONTROL OF POINTING AND TRACKING MANEUVERS**

THOMAS A. W. DWYER, III and JINHO KIM (Illinois, University, Urbana) IN: 1989 American Control Conference, 8th, Pittsburgh, PA, June 21-23, 1989, Proceedings, Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 1131-1135. Research supported by SDIO. refs

(Contract F49620-87-C-0103; NAG1-613)

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It is shown how multiaxial spacecraft tracking and pointing maneuvers with known control bandwidth and given tracking error bounds can be implemented by variable-structure control in the presence of uncertain vehicle and target dynamics. It is shown how to select a nonlinear sliding surface relating attitude and rate variables, as well as a Lyapunov function in the surface variables that absorbs multiplicative model uncertainties, thereby simplifying the computation of control corrections. It is then shown how a boundary layer envelope can be designed, within which the components of the surface error dynamics can be modeled as the outputs of designer-selected decoupled low-pass filters. Closed-loop stability conditions accounting for the coupling between the attitude error dynamics and the surface error dynamics are then obtained. I.E.

AB9-54019\* State Univ. of New York, Buffalo.

**DISTRIBUTED PARAMETER ACTUATORS FOR STRUCTURAL CONTROL**

H. H. CUDNEY, D. J. INMAN (New York, State University, Buffalo), and Y. OSHMAN (Technion - Israel Institute of Technology, Haifa) IN: 1989 American Control Conference, 8th, Pittsburgh, PA, June 21-23, 1989, Proceedings, Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 1189-1194. refs (Contract NGT-33-183-802; F49620-86-C-0111)

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Timoshenko beam theory is applied to beams with multiple layers of piezoelectric material attached. The model is developed using a Hamiltonian approach, and includes the external electrical circuit as well as a complete set of boundary conditions. Resistors are added to the sensor layers for passive damping. The resulting model is then formulated in state space. I.E.

AB9-54031

**SECAFLEX - AN EXPERIMENTAL SET-UP FOR THE STUDY OF ACTIVE CONTROL OF FLEXIBLE STRUCTURES**

JEAN-PIERRE CHRETIEN (ONERA, Centre d'Etudes et de Recherches de Toulouse, France) IN: 1989 American Control Conference, 8th, Pittsburgh, PA, June 21-23, 1989, Proceedings, Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 1397-1402. Research supported by DRET.

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A research program has been conducted for several years on

a general methodology of control of mechanical flexible structures, and a facility named SECAFLEX has been built to investigate experimentally the various issues of this topic. The goals and design features of such an environment are discussed. The selected architecture, a two-degrees-of-freedom flexible manipulator, is then presented with emphasis on the dimensioning of the actuators to provide effective interaction between flexible modes and control. Problems due to in-joint friction and backlash, which led to the inclusion of local torque-meters, are investigated. I.E.

A89-54036

#### ATTITUDE OSCILLATION DAMPING FOR SPACE STATION FREEDOM ALTERNATIVE ASSEMBLY CONFIGURATIONS

JAMES W. WADE (Lockheed Engineering and Sciences Co., Houston, TX) IN: 1989 American Control Conference, 8th, Pittsburgh, PA, June 21-23, 1989, Proceedings, Volume 2, New York, Institute of Electrical and Electronics Engineers, 1989, p. 1573-1578. refs

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Studies were conducted to investigate two types of passive magnetic dampers as stabilization methods for the Space Station Freedom. Achievement of a fully functioning vehicle with communication, control, and reboost capability after the first flight is constrained by the space shuttle's size and lift capabilities. Magnetic dampers require no power or communication ability to operate. When used on properly manifested spacecraft, magnetic dampers provide a lightweight, inexpensive, proven method of passively damping attitude oscillations. Some of the results of a study conducted to determine the possibility of using magnetic dampers on alternative configurations for Freedom are presented. I.E.

A89-54040\* National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

#### ORTHOGONAL CANONICAL FORMS FOR SECOND-ORDER SYSTEMS

TREVOR WILLIAMS (NASA, Langley Research Center, Hampton, VA) and ALAN LAUB (California, University, Santa Barbara) IN: 1989 American Control Conference, 8th, Pittsburgh, PA, June 21-23, 1989, Proceedings, Volume 2, New York, Institute of Electrical and Electronics Engineers, 1989, p. 1621, 1622. refs

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The authors prove that a linear second-order system with arbitrary damping cannot be reduced to Hessenberg-triangular form by means of orthogonal transformations, while this reduction is always possible for the modal damping commonly assumed for models of flexible structures. The type of canonical form obtainable by means of orthogonal transformations acting on a second-order system is heavily dependent on the type of damping considered. If the damping matrix is merely positive semi-definite symmetric, it is generally not possible to obtain a reduction to Hessenberg-triangular form, while this reduction is trivial for zero or Rayleigh damping. If damping is modal, however, as is commonly assumed in structural models, the reduction exists and is nontrivial. Furthermore, reduction to triangular second-order Schur form is always possible for such damping; this canonical form appears likely to have applications to second-order system theory. I.E.

A89-54042

#### A DECENTRALIZED MINIMUM STATE ERROR VARIANCE CONTROLLER FOR LARGE FLEXIBLE SPACE STRUCTURES

PREMAL DESAI, KWANG Y. LEE, and TOM POTTER (Pennsylvania State University, University Park) IN: 1989 American Control Conference, 8th, Pittsburgh, PA, June 21-23, 1989, Proceedings, Volume 2, New York, Institute of Electrical and Electronics Engineers, 1989, p. 1642-1644. refs

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A decentralized approach is considered for developing the solution of the motion control problem of large flexible space structures. A minimum state error variance control philosophy has been used to develop a decentralized state feedback controller

that minimizes a single-step quadratic performance index at each control location. The resulting controller uses a decentralized Kalman predictor and is relatively simple to implement. I.E.

A89-54059

#### A CASE STUDY IN CONTROL DESIGN AND IMPLEMENTATION FOR FLEXIBLE STRUCTURE SYSTEMS

UMIT OZGUNER, STEPHEN YURKOVICH (Ohio State University, Columbus), and ROBERT W. GORDON (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH) IN: 1989 American Control Conference, 8th, Pittsburgh, PA, June 21-23, 1989, Proceedings, Volume 3, New York, Institute of Electrical and Electronics Engineers, 1989, p. 2085-2090. refs

(Contract F33615-87-C-3257)

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A description is given of a complete case study, from design to actual implementation, for active vibration control on an experimental flexible structure. The laboratory apparatus consists of a vertical cantilevered beam configuration with a disk at the free end. The mathematical model developed for control design (reported previously) accounts for dynamics due to the structure and actuators. Several control design approaches have been implemented, including decentralized linear quadratic Gaussian, overlapping decomposition, and fixed-order dynamic compensation (optimal projection) techniques. Results are presented, and comparisons are made for the various control design methods chosen. I.E.

A89-54061

#### EXPERIMENTAL TEST-BED FOR A SINGLE LINK FLEXIBLE MANIPULATOR

EDUARDO M. NEBOT, GORDON K. F. LEE, and THOMAS BRUBAKER (Colorado State University, Fort Collins) IN: 1989 American Control Conference, 8th, Pittsburgh, PA, June 21-23, 1989, Proceedings, Volume 3, New York, Institute of Electrical and Electronics Engineers, 1989, p. 2096-2101. refs

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The manipulator, computer resources, and data acquisition board are described. A detailed description presentation of the collocated sensors available is also given. Noncollocated control of flexible manipulators is a very difficult task. For this purpose a wide-field noncollocated sensor was developed and is presented in detail. A software package and interface have been developed to obtain the frequency response of the arm when it is excited by different patterns. This tool proves to be very useful and reliable in obtaining the actual frequency response of the arm to compare with the responses obtained by online algorithms. I.E.

A89-54078

#### PRELIMINARY RESULTS ON THE DESIGN OF A ROBOTIC TENTACLE END EFFECTOR

DAVID C. NEMIR (Texas, University, El Paso) IN: 1989 American Control Conference, 8th, Pittsburgh, PA, June 21-23, 1989, Proceedings, Volume 3, New York, Institute of Electrical and Electronics Engineers, 1989, p. 2374-2376. Research supported by the Texas Higher Education Coordinating Board. refs

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Preliminary results are given on the design of a nitinol-based robotic tentacle. By electrically heating specific segments in nitinol wires which have been annealed to a nautilus shape, the tentacle can be controlled to assume a variety of shapes and orientations. A simple experiment demonstrating feasibility is discussed. I.E.

A89-54089

#### MODELING AND ROBUSTNESS ISSUES IN CONTROL DESIGN FOR FLEXIBLE STRUCTURES

M. G. SAFONOV and H. FLASHNER (Southern California, University, Los Angeles, CA) IN: 1989 American Control Conference, 8th, Pittsburgh, PA, June 21-23, 1989, Proceedings, Volume 3, New York, Institute of Electrical and Electronics Engineers, 1989, p. 2527-2531. refs

(Contract AF-AFOSR-88-0282)

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The key properties of any model to be used for control design are discussed and quantified by a robustness theorem. The validity of the assumptions which go into generating large finite-element models of flexible structures are examined, and possible pitfalls are pointed out. While the robustness theorem indicates that substantial model inaccuracies can be tolerated, certain gross inaccuracies in the model can lead to qualitatively different system characteristics, resulting in deficient and possibly unstable designs. In particular, small variations in sensor locations or system parameters can interchange the ordering of poles and zeros or even move some zeros into the RHP, producing phase errors of up to -360 deg. I.E.

A89-54094

# IDENTIFICATION FOR ROBUST CONTROL OF FLEXIBLE STRUCTURES

GARY J. BALAS and JOHN C. DOYLE (California Institute of Technology, Pasadena) IN: 1989 American Control Conference, 8th, Pittsburgh, PA, June 21-23, 1989, Proceedings, Volume 3. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2566-2571. Research supported by California Institute of Technology. refs  
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An accurate multivariable transfer function model of an experimental structure is required for research involving robust control of flexible structures. Initially, a multi-input/multi-output model of the structure is generated using the finite-element method. This model does not reproduce the experimental data. Therefore, Chebyshev polynomials are employed to fit the data with a single-input/multi-output transfer function model. Combining these leads to a multivariable model with more modes than the original finite-element model. To find a physically motivated model, an ad hoc model reduction technique which uses a priori knowledge of the structure is developed. The ad hoc approach is compared with balanced realization model reduction to determine its benefits. Plots of select transfer function models and experimental data are included. I.E.

A89-54114\* SDRC, Inc., San Diego, CA.

# MODAL REPRESENTATIONS IN CONTROL/STRUCTURE INTERACTION

PAUL A. BILLOCH, JEFFREY W. YOUNG (SDRC, Inc., Engineering Services Div., San Diego, CA), and KELLY S. CARNEY (NASA, Lewis Research Center, Cleveland, OH) IN: 1989 American Control Conference, 8th, Pittsburgh, PA, June 21-23, 1989, Proceedings, Volume 3. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2802-2807. refs  
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When control/structure interaction problems are examined, a standard method for representing the structure is to choose a truncated set of normal modes calculated from either a finite-element or a distributed-parameter model. However, the normal modes can neglect important static information about the structure. Using a set of fixed interface modes results in a much more accurate closed-loop model, even when relatively low-bandwidth controllers are used. The fixed interface modes are calculated with control input degrees of freedom held fixed, and standard finite-element software can be used. Illustrative examples include a simple hinged beam and a complex model of the phase-I Space Station configuration. I.E.

A89-54115\* Virginia Polytechnic Inst. and State Univ., Blacksburg.

# DECENTRALIZED CONTROL OF THE COFS-I MAST USING LINEAR DC MOTORS

DOUGLAS K. LINDNER, TOM CELANO (Virginia Polytechnic Institute and State University, Blacksburg), and ERIC IDE (General Electric Co., Syracuse, NY) IN: 1989 American Control Conference, 8th, Pittsburgh, PA, June 21-23, 1989, Proceedings, Volume 3. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2808-2812. refs  
(Contract NAG1-719; NAG1-840)  
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Consideration is given to a decentralized control design for vibration suppression in the COFS-I Mast using linear dc motors for actuators. The decentralized control design is based results from power systems using root locus techniques that are not well known. The approach is effective because the loop gain is low due to low actuator authority. The frequency-dependent nonlinearities of the actuator are taken into account. Because of the tendency of the transients to saturate the stroke length of the actuator, its effectiveness is limited. I.E.

N89-20151\*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.

# FLEXIBLE STRUCTURE CONTROL LABORATORY DEVELOPMENT AND TECHNOLOGY DEMONSTRATION Final Report

H. C. VIVIAN, P. E. BLAIRE, D. B. ELDRED, G. E. FLEISCHER, C.-H. C. IH, N. M. NERHEIM, R. E. SCHEID, and J. T. WEN 1 Oct. 1987 213 p  
(Contract NAS7-918)  
(NASA-CR-184867; JPL-PUBL-88-29; NAS 1.26:184867) Avail: NTIS HC A10/MF A02 CSCL 22B

An experimental structure is described which was constructed to demonstrate and validate recent emerging technologies in the active control and identification of large flexible space structures. The configuration consists of a large, 20 foot diameter antenna-like flexible structure in the horizontal plane with a gimbaled central hub, a flexible feed-boom assembly hanging from the hub, and 12 flexible ribs radiating outward. Fourteen electrodynamic force actuators mounted to the hub and to the individual ribs provide the means to excite the structure and exert control forces. Thirty permanently mounted sensors, including optical encoders and analog induction devices provide measurements of structural response at widely distributed points. An experimental remote optical sensor provides sixteen additional sensing channels. A computer samples the sensors, computes the control updates and sends commands to the actuators in real time, while simultaneously displaying selected outputs on a graphics terminal and saving them in memory. Several control experiments were conducted thus far and are documented. These include implementation of distributed parameter system control, model reference adaptive control, and static shape control. These experiments have demonstrated the successful implementation of state-of-the-art control approaches using actual hardware. Author

N89-20180\*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.

# ACTIVE SPACECRAFT POTENTIAL CONTROL: AN ION EMITTER EXPERIMENT

W. RIEDLER, R. GOLDSTEIN, M. HAMELIN, B. N. MAEHLUM, J. TROM, R. C. OLSEN, A. PEDERSEN, R. J. L. GRARD, R. SCHMIDT, F. RUDENAUER (Oesterreichisches Forschungszentrum Seibersdorf G.m.b.H., Vienna) et al. IN: ESA, The Cluster Mission: Scientific and Technical Aspects of the Instruments p 95-102 Oct. 1988

Avail: NTIS HC A06/MF A01; ESA Publications Div., ESTEC, Noordwijk, Netherlands, \$10 US or 25 Dutch guilders

The cluster spacecraft are instrumented with ion emitters for charge neutralization. The emitters produce indium ions at 6 keV. The ion current is adjusted in a feedback loop with instruments measuring the spacecraft potential. The system is based on the evaporation of indium in the apex field of a needle. The design of the active spacecraft potential control instruments, and the ion emitters is presented. ESA

N89-20470\*# Georgia Inst. of Tech., Atlanta. School of Mechanical Engineering.

# ACTIVE VIBRATION CONTROL OF A LARGE FLEXIBLE MANIPULATOR BY INERTIAL FORCE AND JOINT TORQUE Ph.D. Thesis

SOO HAN LEE Jun. 1988 18 p  
(Contract NAG1-623)  
(NASA-CR-184786; NAS 1.26:184786) Avail: NTIS HC A03/MF A01 CSCL 13/9



The efficiency and positional accuracy of a lightweight flexible manipulator are limited by its flexural vibrations, which last after a gross motion is completed. The vibration delays subsequent operations. In the proposed work, the vibration is suppressed by inertial force of a small arm in addition to the joint actuators and passive damping treatment. The proposed approach is: (1) Dynamic modeling of a combined system, a large flexible manipulator and a small arm, (2) Determination of optimal sensor location and controller algorithm, and (3) Verification of the fitness of model and the performance of controller. Author

**N89-21016#** Control Dynamics Co., Huntsville, AL.  
**ACTIVE CONTROL TECHNIQUE EVALUATION FOR SPACECRAFT (ACES) Final Report, 15 Aug. 1986 - 30 Jul. 1987**

R. D. IRWIN, VICTORIA JONES, SALLY C. RICE, SHERMAN M. SELTZER, and DANNY K. TOLLISON 16 Jun. 1988 242 p  
(Contract F33615-86-C-3225)  
(AD-A202475; AFVAL-TR-88-3038) Avail: NTIS HC A11/MF A02 CSCL 22/2

This report describes the Active Control Technique Evaluation for Spacecraft (ACES) Program. Three Large Space Structures control system design techniques, developed under the Active Control of Space Structures (ACOSS) Program, were compared. The three techniques included Filter Accommodated Model Error Sensitivity Suppression (FAMESS), High Authority Control/Low Authority Control (HAC/LAC), and Positivity. The comparison was accomplished both analytically and experimentally. Each controller was implemented and tested at the NASA/MSFC Large Space Structure Ground Test Facility on the ACES test article. The design and implementation of each controller were performed under identical conditions. The identical control model, sensor/actuator complement, computer, disturbances, and performance criteria were applied to each control design/evaluation. GRA

**N89-21018#** Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.

**REMOTE ORBITAL CAPTURE USING AN ORBITAL MANEUVERING VEHICLE EQUIPPED WITH A MULTIBODY GRAPPLING ARM ASSEMBLY M.S. Thesis**

F. JOSEPH BISHOP Dec. 1988 165 p  
(AD-A202760; AFIT/GA/AA/88D-02) Avail: NTIS HC A08/MF A01 CSCL 22/1

The problem of detumbling and despinning a freely spinning and precessing axisymmetric target satellite using an orbital maneuvering vehicle is considered. The axisymmetric orbital maneuvering vehicle is equipped with a multibody grappling arm assembly to capture the target. Counter-masses are used to maintain dynamic balancing and stability throughout the deployment of the arm and the subsequent spin-up of the grappling device prior to docking. The five-body system is modeled using Eulerian-based equations of motion developed by Hooker and Margulies. Open-loop control laws are formulated to deploy the grappling arm assembly and spin-up the grappling device using internal motor torques. A Liapunov technique is applied to derive a nonlinear feedback control law that drives the docked system to a final spin-stabilized state of equilibrium. External thrusters are used to maintain the absolute motion of the system during this process. Variations in grappling length, target coning angle, and response times are examined for design purposes. State and control histories are presented and the results from this five-body model are compared with the Widhalm and Conway two-body study. The simulation indicates that the required control magnitudes are higher for the five-body model but are still quite reasonable. The addition of the grappling arm assembly adds both realism and flexibility to the capture process. GRA

**N89-21020#** Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.

**ACTIVE CONTROL OF A LARGE SPACE STRUCTURE AS APPLIED TO THE PHASE 1 CETF (CRITICAL EVALUATION TASK FORCE) SPACE STATION M.S. Thesis**

DALE A. COPE Dec. 1988 117 p  
(AD-A203293; AFIT/GAE/AA/88D-5) Avail: NTIS HC A06/MF A01 CSCL 22/5

The major objective of this thesis is to apply a decoupled control technique to a specific space station model. The model is a finite element model of the Phase 1 Critical Evaluation Task Force (CETF) Space Station. The control technique allows for the active control of a large number of modes by using several decoupled controllers. The space station attitude control system provides attitude stabilization and disturbance rejection. Its performance is evaluated by the station's response to two disturbances - crew motion and shuttle docking. GRA

**N89-21028#** Draper (Charles Stark) Lab., Inc., Cambridge, MA.  
**RCS/LINEAR DISCRETE ACTUATOR STUDY Final Report, Aug. 1985 - Jan. 1988**

THOMAS BAILEY, ALEXANDER GRUZEN, and PAUL MADDEN Aug. 1988 299 p  
(Contract F04611-85-K-0051)  
(AD-A202822; CSDL-R-2075; AFAL-TR-88-039) Avail: NTIS HC A13/MF A02 CSCL 22/2

The objective of the program was to develop the technology and demonstrate the use of linear discrete actuators combined with a rocket control system (RCS) to control the large angle slew and fine pointing/tracking of a simulated large flexible space structure. The linear actuators included proof-mass actuators, and a hub torquer to simulate a control moment gyro or reaction wheel actuator. The demonstration used the CSDL/AFAL ground test facility located at CSDL, Inc. The facility comprises the flexible test structure and actuators which are mounted on a low-friction, air-bearing table, and associated test instrumentation. The combined linear discrete and RCS actuators demonstrated significantly improved fine pointing/tracking a vibration suppression capability relative to the uses of the RCS alone. GRA

**N89-21743\*#** Ohio Univ., Athens. Dept. of Electrical and Computer Engineering.

**INVESTIGATION OF PRACTICAL APPLICATIONS OF H INFINITY CONTROL THEORY TO THE DESIGN OF CONTROL SYSTEMS FOR LARGE SPACE STRUCTURES**

R. DENNIS IRWIN in Alabama Univ., Research Reports: 1988 NASA/ASEE Summer Faculty Fellowship Program 26 p Dec. 1988

Avail: NTIS HC A99/MF E03 CSCL 22/2

The applicability of H infinity control theory to the problems of large space structures (LSS) control was investigated. A complete evaluation to any technique as a candidate for large space structure control involves analytical evaluation, algorithmic evaluation, evaluation via simulation studies, and experimental evaluation. The results of analytical and algorithmic evaluations are documented. The analytical evaluation involves the determination of the appropriateness of the underlying assumptions inherent in the H infinity theory, the determination of the capability of the H infinity theory to achieve the design goals likely to be imposed on an LSS control design, and the identification of any LSS specific simplifications or complications of the theory. The results of the analytical evaluation are presented in the form of a tutorial on the subject of H infinity control theory with the LSS control designer in mind. The algorithmic evaluation of H infinity for LSS control pertains to the identification of general, high level algorithms for effecting the application of H infinity to LSS control problems, the identification of specific, numerically reliable algorithms necessary for a computer implementation of the general algorithms, the recommendation of a flexible software system for implementing the H infinity design steps, and ultimately the actual development of the necessary computer codes. Finally, the state of the art in H infinity applications is summarized with a brief outline of the most promising areas of current research. Author

**N89-21828#** General Research Corp., McLean, VA.  
**AN EXPERT SYSTEM APPROACH TO LARGE SPACE SYSTEMS CONTROL Technical Report, Sep. 1987 - Oct. 1988**  
CHARLES F. GARTRELL, WILLIAM BARACAT, and BARBARA

SKIFFINGTON Oct. 1988 260 p  
(Contract F49620-87-C-0105)  
(AD-A204460; AFOSR-89-0003TR) Avail: NTIS HC A12/MF A02  
CSCL 12/9

The purpose of this project was to develop a technique which will reduce the need for high fidelity models for the control synthesis process, provide a robust control implementation, and relieve computational burdens by utilizing artificial intelligence techniques, notably expert systems, to implement control systems for large SDI space systems. Extending an earlier proof-of-concept investigation, this research proceeds beyond simple control laws, low bandwidths, and exact pattern encoding/matching approaches to include modern control laws, higher bandwidths, and partial match inferencing procedures. Three control implementations, Direct Velocity Feedback, Independent Modal Space Control and an Expert System Controller were developed and various simulations performed to verify and compare performance. The primary finding is that an ESC has performance comparable to the numeric approaches and has a superior performance when there are changes in the system being controlled. That is, an ESC indeed demonstrates a robust control implementation. GRA

**N89-21829#** Vista Research Corp., Mountain View, CA.  
**ADAPTIVE CONTROL TECHNIQUES FOR LARGE SPACE STRUCTURES** Final Technical Report, 1 Jun. 1987 - 30 Sep. 1988

ROBERT L. KOSUT 6 Jan. 1989 71 p  
(Contract F49620-85-C-0094)  
(AD-A204530; ISI-150; AFOSR-89-0071TR) Avail: NTIS HC  
A04/MF A01 CSCL 22/1

The Large Space Structure (LSS) research program was originally formulated in late 1982 in response to the increasing concern that performance robustness of Air Force LSS type system would be inadequate to meet mission objectives. In particular, uncertainties in both system dynamics and disturbance spectra characterizations (both time varying and stochastic uncertainty) significantly limit the performance attainable with fixed gain, fixed architecture controls. Therefore, the use of an adaptive system, where disturbances and/or plant models are identified prior to or during control, gives systems designers more options for minimizing the risk in achieving performance objectives. The aim of adaptive control is to implement in real-time and on-line as many as possible of the design functions now performed off-line by the control engineer; to give the controller intelligence. To realize this aim, both a theory of stability and performance of such inherently nonlinear controls is essential as well as a technology capable of achieving the implementation. The issues of performance sensitivity, robustness, and achievement of very high performance in an LSS system can be effectively address using adaptive algorithms. GRA

**N89-21830#** Virginia Univ., Charlottesville. Dept. of Applied Mathematics.

**INCREASING THE MARGIN OF STABILITY OF ARBITRARILY FINITE MODES OF FLEXIBLE LARGE SPACE STRUCTURES WITH DAMPING** Final Report, 1 Sep. 1986 - 31 Mar. 1988

I. LASIECKA and R. TRIGGIANA 26 May 1988 9 p  
(Contract AF-AFOSR-0365-84; AF PROJ. 2304)  
(AD-A204959; UVA/525683/AM88/101; AFOSR-89-0211TR)  
Avail: NTIS HC A02/MF A01 CSCL 12/1

Major themes of research performed under the grant include:  
(1) increasing the margin of stability of arbitrarily finite modes of damped wave equations. Allocation of spectrum and of Riesz basis properties of eigenvectors; (2) uniform stabilization (linear case) and strong stabilization (non-linear case) by a priori, explicit boundary feedbacks for waves and plates; (3) exact boundary controllability for waves and plates; (4) study of the optimal quadratic cost problem for waves and plates, in particular of the associated Algebraic Riccati Equation which produces a boundary feedback based on the Riccati operator which uniformly stabilizes the system (compare with (2)); (5) structural damping for elastic systems under a natural, broad class of damping operators, and

(6) numerical aspects related to some of the topics listed above, in particular related to the computation of the Riccati operator in case of boundary control problems for waves and plates. GRA

**N89-23505#** Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.

**AN ANALYSIS OF THE ATTITUDE STABILITY OF A SPACE STATION SUBJECT TO PARAMETRIC EXCITATION OF PERIODIC MASS MOTION** M.S. Thesis

THOMAS E. WILLIAMS Dec. 1988 103 p  
(AD-A206009; AFIT/GSO/AA/88D-2) Avail: NTIS HC A06/MF  
A01 CSCL 22/1

The future space station will contain a mechanism that transports mass across large distances of its surface. Accordingly, this study will derive the equations of attitude motion for a gravity-gradient stabilized space station whose moments of inertia are varying with time. The equations are linearized, after which Hill's Equation is used to determine pitch stability, while the Method of Multiple Scales is used to determine the roll/yaw stability of the system. Results show that for certain frequencies of mass motion, attitude motion can grow boundlessly with time. Consequently, the shape of the classical Lagrange stability region is altered. GRA

**N89-23896#** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.

**DESIGN, FABRICATION AND TEST OF A 4750 NEWTON-METER-SECOND DOUBLE GIMBAL CONTROL MOMENT GYROSCOPE**

LEWIS COOK, PAUL GOLLEY, HENNING KROME, JOSEPH BLONDIN, CHARLES GURRISI, and JOHN KOLVEK (Allied Signal Corp., Teterboro, NJ.) In: *The 23rd Aerospace Mechanisms Symposium* p 59-76 Mar. 1989

Avail: NTIS HC A15/MF A02 CSCL 14/2

The development of a prototype Control Moment Gyroscope (CMG) is discussed. Physical characteristics and the results of functional testing are presented to demonstrate the level of system performance obtained. Particular attention is given to how the man-rated mission requirement influenced the choice of the materials, fabrication, and design details employed. Comparisons are made of the measured system responses against the prediction generated by computer simulation. Author

**N89-23897#** AEC-Able Engineering Co., Inc., Goleta, CA.  
**CAROUSEL DEPLOYMENT MECHANISM FOR COILABLE LATTICE TRUSS**

ROBERT M. WARDEN and P. ALAN JONES In: *NASA, Marshall Space Flight Center, The 23rd Aerospace Mechanisms Symposium* p 77-100 Mar. 1989

Avail: NTIS HC A15/MF A02 CSCL 13/9

The development of a mechanism for instrumentation and solar-array deployment is discussed. One part of the technology consists of a smart motor which can operate in either an analog mode to provide high speed and torque, or in the stepper mode to provide accurate positioning. The second technology consists of a coilable lattice mast which is deployed and rotated about its axis with a common drive system. A review of the design and function of the system is presented. Structural and thermal test data are included. Author

**N89-24426** Howard Univ., Washington, DC.  
**ON THE DYNAMICS AND CONTROL OF THE SPACECRAFT CONTROL LABORATORY EXPERIMENT (SCOLE) CLASS OF OFFSET FLEXIBLE SYSTEMS** Ph.D. Thesis

CHEICK MODIBO DIARRA 1987 201 p  
Avail: Univ. Microfilms Order No. DA8810423

A mathematical model is developed to predict the dynamics of the proposed orbiting Spacecraft Control Laboratory Experiment during the station keeping phase. The Shuttle as well as the reflector are assumed to be rigid, the mast is flexible and is assumed to undergo elastic displacements very small as compared with its length. The equations of motion are derived using a Newton-Euler formulation. The model includes the effects of gravity,

flexibility, and orbital dynamics. The control is assumed to be provided to the system through the Shuttle's three torquers, and through six actuators located by pairs at two points on the mast and at the mass center of the reflector. At each of the locations, an actuator acts parallel to the roll axis while the other one acts parallel to the pitch axis. The modal shape functions are derived using the fourth order beam equation. The generic mode equations are derived to account for the effects of the control forces on the modal shapes and frequencies. The equations are linearized about a nominal equilibrium position. When the interface point between the mast and the reflector is assumed to coincide with the mass center of the reflector, it is seen that the pitch equation is decoupled from the roll and yaw motions. When the interface point is offset along the roll axis the pitch equation is still decoupled from the two other equations (roll and yaw). It is seen that the open loop system is unstable for both cases due to the (gravitationally) unfavorable moment of inertia distribution. When, in addition to the roll axis offset, a pitch axis offset is introduced into the system, the equations describing the roll, pitch, and yaw motions are seen to be all coupled together. It is further seen that, in the presence of gravity gradient torques in the system dynamics, the system assumes a new equilibrium position about which the equations will have to be linearized.

Dissert. Abstr.

**N89-24863\*** Massachusetts Inst. of Tech., Cambridge.

**APPLICATION OF FINITE-ELEMENT METHODS TO DYNAMIC ANALYSIS OF FLEXIBLE SPATIAL AND CO-PLANAR LINKAGE SYSTEMS, PART 2**

STEVEN DUBOWSKY In NASA, Langley Research Center, Computational Methods for Structural Mechanics and Dynamics p 459-489 May 1989

Avail: NTIS HC A12/MF A02 CSCL 13/9

An approach is described to modeling the flexibility effects in spatial mechanisms and manipulator systems. The method is based on finite element representations of the individual links in the system. However, it should be noted that conventional finite element methods and software packages will not handle the highly nonlinear dynamic behavior of these systems which results from their changing geometry. In order to design high-performance lightweight systems and their control systems, good models of their dynamic behavior which include the effects of flexibility are required.

Author

**N89-24844# Rockwell International Corp., Downey, CA. ORU GUIDELINES FOR TELEROBOTIC COMPATIBILITY Abstract Only**

MARGARET M. CLARKE and DAVOUD MANOUCHEHRI In Tactical Weapons Guidance and Control Information Conference on Space and Military Applications of Automation and Robotics p 49 Jun. 1988

Avail: NTIS HC A05/MF A01 CSCL 09/2

Design guidelines are being developed for remotely maintainable Orbital Replacement Units (ORUs) for on-orbit payloads. The quantity, complexity, and cost of on-orbit payloads will increase significantly over the next few years. These payloads will need service and maintenance as their ORUs need resupply or replacement. On-orbit maintenance can be performed by an extra vehicular activity (EVA) astronaut or by telerobotic devices. NASA and the Department of Defense are interested in concepts for ORU standardization so that payloads can be efficiently serviced by telerobotic devices. A three-step approach was followed in developing guidelines for remotely servicable ORUs: telerobotic concepts; ORU concepts and guidelines; and laboratory verification. During step one, a concept was developed for a telerobotic device capable of performing remote maintenance on a wide variety of ORUs. The concept included reach, degrees of freedom, speed and mass handling capability, and end effector description. During step two, specific guidelines were established for ORU compatibility with such a telerobotic device, including descriptions of fasteners; latches; fluid, electric, and fiber optic connectors; racks; and packaging. During step three, hard mockups were fabricated of several types of ORUs for example, standard data processor black boxes. The boxes were then successfully changed out in the

Rockwell Automation and Robotics (A/R) Facility using a seven degree of freedom master/slave telerobotic device and television writing.

Author

**N89-25223\*** Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.

**OPTIMIZATION OF STRUCTURE AND CONTROL SYSTEM**

N. S. KHOT and RAMANA V. GRANDHI (Wright State Univ., Dayton, OH.) In NASA, Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 3 p 1381-1392 Apr. 1989

Avail: NTIS HC A22/MF A03 CSCL 01/3

The objective of this study is the simultaneous design of the structural and control system for space structures. This study is focused on considering the effect of the number and the location of the actuators on the minimum weight of the structure, and the total work done by the actuators for specified constraints and disturbance. The controls approach used is the linear quadratic regulator theory with constant feedback. At the beginning collocated actuators and sensors are provided in all the elements. The actuator doing the least work is removed one at a time, and the structure is optimized for the specified constraints on the closed-loop eigenvalues and the damping parameters. The procedure of eliminating an actuator is continued until an acceptable design satisfying the constraints is obtained. The study draws some conclusions on the trade between the total work done by the actuators, and the optimum weight and the number of actuators.

Author

**N89-25227\*** Jet Propulsion Lab., California Inst. of Tech., Pasadena. Applied Technologies Section.

**OPTIMAL PLACEMENT OF EXCITATIONS AND SENSORS BY SIMULATED ANNEALING**

MOKTAR SALAMA, R. BRUNO, G.-S. CHEN, and J. GARBA In NASA, Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 3 p 1441-1457 Apr. 1989

Avail: NTIS HC A22/MF A03 CSCL 14/2

The optimal placement of discrete actuators and sensors is posed as a combinatorial optimization problem. Two examples for truss structures were used for illustration; the first dealt with the optimal placement of passive dampers along existing truss members, and the second dealt with the optimal placement of a combination of a set of actuators and a set of sensors. Except for the simplest problems, an exact solution by enumeration involves a very large number of function evaluations, and is therefore computationally intractable. By contrast, the simulated annealing heuristic involves far fewer evaluations and is best suited for the class of problems considered. As an optimization tool, the effectiveness of the algorithm is enhanced by introducing a number of rules that incorporate knowledge about the physical behavior of the problem. Some of the suggested rules are necessarily problem dependent.

Author

**N89-25263\*** National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, TX.

**SMART TUNNEL: DOCKING MECHANISM Patent Application**

JOHN A. SCHLIESING, inventor (to NASA) and KEVIN L. EDENBOROUGH, inventor (to NASA) 30 Dec. 1988 16 p (NASA-CASE-MSC-21360-1; NAS 1.71:MSC-21360-1; US-PATENT-APPL-SN-292131) Avail: NTIS HC A03/MF A01 CSCL 22/2

A docking mechanism is presented for the docking of a space vehicle to a space station comprising a flexible tunnel frame structure which is deployable from the space station. The tunnel structure comprises a plurality of series connected frame sections, one end section of which is attached to the space station and the other end attached to a docking module of a configuration adapted for docking in the payload bay of the space vehicle. The docking module is provided with trunnions, adapted for latching engagement with latches installed in the vehicle payload bay and with hatch means connectable to a hatch of the crew cabin of the space vehicle. Each frame section comprises a pair of spaced



ring members, interconnected by actuator-attenuator devices which are individually controllable by an automatic control means to impart relative movement of one ring member to the other in six degrees of freedom of motion. The control means includes computer logic responsive to sensor signals of range and attitude information, capture latch condition, structural loads, and actuator stroke for generating commands to the onboard flight control system and the individual actuator-attenuators to deploy the tunnel to effect a coupling with the space vehicle and space station after coupling. A tubular fluid-impenious liner, preferably fabric, is disposed through the frame sections of a size sufficient to accommodate the passage of personnel and cargo. NASA

**N89-26022\*** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

**AUTONOMOUS FREQUENCY DOMAIN IDENTIFICATION: THEORY AND EXPERIMENT**

YOUNG YAM, D. S. BAYARD, F. Y. HADAEH, E. METTLER, M. H. MILMAN, and R. E. SCHEID 15 Apr. 1989 218 p

(Contract NAS7-918)

(NASA-CR-184811; JPL-PUBL-89-8; NAS 1.26:184811) Avail: NTIS HC A10/MF A02 CSCL 22/1

The analysis, design, and on-orbit tuning of robust controllers require more information about the plant than simply a nominal estimate of the plant transfer function. Information is also required concerning the uncertainty in the nominal estimate, or more generally, the identification of a model set within which the true plant is known to lie. The identification methodology that was developed and experimentally demonstrated makes use of a simple but useful characterization of the model uncertainty based on the output error. This is a characterization of the additive uncertainty in the plant model, which has found considerable use in many robust control analysis and synthesis techniques. The identification process is initiated by a stochastic input  $u$  which is applied to the plant  $p$  giving rise to the output. Spectral estimation ( $\hat{h} = P \text{ sub } u/P \text{ sub } u$ ) is used as an estimate of  $p$  and the model order is estimated using the produce moment matrix (PMM) method. A parametric model unit direction vector  $p$  is then determined by curve fitting the spectral estimate to a rational transfer function. The additive uncertainty  $\delta \text{ sub } m = p - \text{unit direction vector } p$  is then estimated by the cross spectral estimate  $\delta \text{ sub } u/P \text{ sub } u$  where  $e = y - \text{unit direction vector } y$  is the output error, and unit direction vector  $y = \text{unit direction vector } pu$  is the computed output of the parametric model subjected to the actual input  $u$ . The experimental results demonstrate the curve fitting algorithm produces the reduced-order plant model which minimizes the additive uncertainty. The nominal transfer function estimate unit direction vector  $p$  and the estimate  $\delta$  of the additive uncertainty  $\delta \text{ sub } m$  are subsequently available to be used for optimization of robust controller performance and stability.

Author

**N89-26032\*** North Carolina Univ., Charlotte. Dept. of Electrical Engineering.

**CONTROL OF SPACECRAFT CONTROL LABORATORY EXPERIMENT (SCOLE) SLEW MANEUVERS**

Y. P. KAKAD 1987 28 p

(Contract NAG1-535)

(NASA-CR-185361; NAS 1.26:185361) Avail: NTIS HC A03/MF A01 CSCL 22/2

This is the second report of a set of two reports on the dynamics and control of slewing maneuvers of NASA Spacecraft Control Laboratory Experiment (SCOLE). The control problem of slewing maneuvers of SCOLE is developed in terms of an arbitrary maneuver about any given axis. The control system is developed for the combined problem of rigid-body slew maneuver and vibration suppression of flexible appendage. The control problem is formulated by incorporating the nonlinear equations derived in the previous report and is expressed in terms of a two-point boundary value problem utilizing a quadratic type of performance index. The two-point boundary value problem is solved as a hierarchical control problem with the overall system being split in terms of two subsystems, namely the slewing of the entire assembly and the

vibration suppression of the flexible antenna. The coupling variables between the two dynamical subsystems are identified and these two subsystems for control purposes are treated independently in parallel at the first level. Then the state-space trajectory of the combined problem is optimized at the second level. Author

**N89-26034\*** Oregon Univ., Eugene. Dept. of Computer and Information Science.

**QUALITATIVE MECHANISM MODELS AND THE RATIONALIZATION OF PROCEDURES Final Report**

ARTHUR M. FARLEY 10 Jul. 1989 41 p

(Contract NAG2-383)

(NASA-CR-185452; NAS 1.26:185452) Avail: NTIS HC A03/MF A01 CSCL 22/2

A qualitative, cluster-based approach to the representation of hydraulic systems is described and its potential for generating and explaining procedures is demonstrated. Many ideas are formalized and implemented as part of an interactive, computer-based system. The system allows for designing, displaying, and reasoning about hydraulic systems. The interactive system has an interface consisting of three windows: a design/control window, a cluster window, and a diagnosis/plan window. A qualitative mechanism model for the ORS (Orbital Refueling System) is presented to coordinate with ongoing research on this system being conducted at NASA Ames Research Center. K.C.D.

**N89-26208\*** Aerojet TechSystems Co., Sacramento, CA.

**INTEGRATED CONTROL AND HEALTH MONITORING CAPACITIVE DISPLACEMENT SENSOR DEVELOPMENT TASK. ORBIT TRANSFER ROCKET ENGINE TECHNOLOGY PROGRAM Final Report**

FRANK N. COLLAMORE Jul. 1989 110 p

(Contract NAS3-23772)

(NASA-CR-182279; NAS 1.26:182279) Avail: NTIS HC A06/MF A01 CSCL 14/2

The development of a miniature multifunction turbomachinery shaft displacement sensor using state-of-the-art non-contact capacitive sensing technology is described. Axial displacement, radial displacement, and speed are sensed using a single probe within the envelope normally required for a single function. A survey of displacement sensing technology is summarized including inductive, capacitive, optical and ultrasonic techniques. The design and operation of an experimental triple function sensor is described. Test results are included showing calibration tests and simultaneous dynamic testing of multiple functions. Recommendations for design changes are made to improve low temperature performance, reliability, and for design of a flight type signal conditioning unit.

Author

**N89-26883\*** Optimization, Inc., Blacksburg, VA.

**CONTROL OF FLEXIBLE STRUCTURES Final Report, 1 Mar. 1986 - 30 Sep. 1988**

JOHN A. BURNS, EUGENE M. CLIFF, H. J. KELLEY, F. H. LUTZE, and R. E. MILLER Apr. 1989 151 p

(Contract F04611-86-C-0008)

(AD-A207520; K511-3; AL-TR-89-001) Avail: NTIS HC A08/MF A01 CSCL 13/13

This report summarizes the work done under contract FO 4611-86-C-0008. The principal goals were to develop state-space models and computational algorithms for control of beam and plate type structures, and, more generally, to increase the understanding of the basic problems associated with this development. The state-space approach is based on a distributed parameter model of the structure that includes the fundamental equations without modal truncation. The approach is to use basic physical principles to write down the governing partial differential equations, construct a state-space model from these governing equations, formulate the optimal control problem in terms of the state-space model, develop a convergent approximation scheme and conduct numerical experiments to test the method. GRA

## 07

## POWER

Includes descriptions of analyses, systems, and trade studies of electric power generation, storage, conditioning and distribution.

ABN-37121

#### HIGH CURRENT DENSITY ALUMINUM STABILIZED CONDUCTOR CONCEPTS FOR SPACE APPLICATIONS

X. HUANG, Y. M. EYSSA, and M. A. HILAL (Wisconsin, University, Madison) (IEEE, Lawrence Livermore National Laboratory, DOE, et al., 1988 Applied Superconductivity Conference, San Francisco, CA, Aug. 21-25, 1988) IEEE Transactions on Magnetics (ISSN 0018-9464), vol. 25, March 1989, p. 1532-1535. refs  
(Contract N00167-87-K-0095)

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The authors report on a high-current-density aluminum-stabilized conductor concept for large spaceborne energy storage inductors. High-purity-aluminum-stabilized NbTi composite conductors cooled by 1.8-K helium can provide a winding current density up to 15 kA/sq cm at fields up to 10 T. The conductors are edge-cooled with enough surface area to provide recovery following a normalizing disturbance. The conductors are designed so that current diffusion time in the high-purity aluminum is smaller than the thermal diffusion time in helium. Conductor design, stability, and current diffusion are considered. The numerical analysis of transient stability shows that aluminum-stabilized conductors with final resistivity ratio greater than 800 can be stable in a 1.8-K pressurized helium II bath up to 50 kA ( $J = 15$  kA/sq cm) at fields up to 10 T. Single-layer toroids are preferred over multilayer ones because of their simplicity of construction, large current requirement, and better magnetoresistance. I.E.

ABN-37127#

#### LIGHTWEIGHT POWER BUS FOR A BASELOAD NUCLEAR REACTOR IN SPACE

CHARLES E. OBERLY, LOWELL D. MASSIE, and DENNIS J. HOFFMANN (USAF, Aero Propulsion Laboratory, Wright-Patterson AFB, OH) (IEEE, Lawrence Livermore National Laboratory, DOE, et al., 1988 Applied Superconductivity Conference, San Francisco, CA, Aug. 21-25, 1988) IEEE Transactions on Magnetics (ISSN 0018-9464), vol. 25, March 1989, p. 1803-1806. Research supported by USAF. refs

Space environmental interactions with the power distribution/power processing subsystem can become a serious problem for power systems rated at tens to hundreds of kilowatts. Utilization of ceramic superconductors at 1000 A/sq cm, which has already been demonstrated at 77 K, in a conductor configuration may eliminate both bus mass and distribution voltage problems in a high-power satellite. The analytical results presented demonstrate that a superconducting coaxial power transmission bus offers significant benefits in reduced distribution voltage and mass. I.E.

ABN-38163

#### NUCLEAR ALKALI METAL THERMOELECTRIC CONVERTER FOR AEROSPACE POWER

TOSHIHISA MASUDA, AKIRA NEGISHI, KOTARO TANAKA, and TAKEO HONDA (Ministry of International Trade and Industry, Electrotechnical Laboratory, Tsukuba, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1031-1036. refs

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An alkali metal thermoelectric converter which uses the sodium ion conducting beta-double-prime alumina to convert heat energy to electric energy is described. The possibility of coupling the converter system with a nuclear reactor for high efficiency and lightweight space power plants is examined. The film electrodes on the surface of disk beta-double-prime-alumina were fabricated

using a magnetron sputtering system with molybdenum target. Tests on the disk cell were conducted, reaching a heat up to 1073 K, with an open voltage of 0.99 V, short circuit current of 1.82 A/sq cm, and a maximum specific power output of 3.4 kWe/sq m. R.B.

ABN-38222

#### PERFORMANCE ESTIMATES OF SOLAR STIRLING AND BRAYTON CYCLE SYSTEMS FOR SPACE POWER GENERATION

KUNIHISA EGUCHI, SACHIO OGIWARA, and YOHJI KUROSAWA (National Aerospace Laboratory, Tokyo, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1423-1430. refs

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The performance characteristics of the solar Stirling and Brayton cycle power systems are analyzed, with special attention given to the conceptual design tradeoffs for a 30-kWe dynamic power module. The 300-400-K range is found to be the optimum radiator temperature level to minimize system mass and aerodynamic drag force for either power module. The advanced solar dynamic power system may increase thermal efficiency by a factor of about four, reduce weight by 40 percent, and decrease air drag by about 60 percent relative to the photovoltaic cell/battery system. R.R.

ABN-38368

#### CONCEPTUAL DESIGN OF PARABOLIC SOLAR CONCENTRATORS

S. KATO, H. ODA, Y. TAKESHITA, Y. SAKAI (Kawasaki Heavy Industries, Ltd., Aircraft Engineering Div., Kakamigahara, Japan), T. NAKAMURA (Kawasaki Heavy Industries, Ltd., Technical Institute, Akashi, Japan) et al. IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 2473-2481.

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A conceptual design study of parabolic solar concentrators was carried out and the mirror segment was fabricated and tested. The configurations of three kinds of collectors (1.5 kw, 10 kw, and 15 kw) were studied. The need to fabricate a new mirror segment with a resin specular surface which would be lighter and whose thermal deflection would be decreased is demonstrated. K.K.

ABN-38369

#### SOLAR HEATING EVALUATION OF LIGHT WEIGHT MIRROR SEGMENTS FOR A SPACE SOLAR CONCENTRATOR

YOSHIHIRO NAKAMURA, MORIO SHIMIZU, and YASUO WATANABE (National Aerospace Laboratory, Chofu, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 2483-2488.

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Four pieces of hexagonal mirror segments with different designs and thicknesses were fabricated for light-weight reflectors of space solar concentrators. By using these segments in solar heating experiments, it was possible to increase the temperature of the heated carbon to a level corresponding to the surface accuracy of each mirror. The concentrations calculated from the temperature data agreed with those estimated from the sun width and the slope error obtained in laser optical measurements. K.K.

ABN-38370

#### INVESTIGATIONS ON SOLAR RECEIVERS FOR CBC POWER SYSTEMS IN ORBIT

K. FURUHAMA, Y. MOCHIDA, S. MATSUDA, T. TOGAWA, Y. SHIMAMOTO (Toshiba Corp., Energy Science and Technology Laboratory, Kawasaki, Japan) et al. IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 2489-2496. refs

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The results of thermal and structural design studies on a 30 kW CBC receiver are presented. Emphasis is placed on the selection of tube and container materials and on comparisons between heat transfer tube types. Lithium fluoride was selected as a phase change material (PCM) because of its significant latent heat and optimal melting point for closed Brayton cycle (CBC) systems. A preliminary design for a 30 kW CBC system resulted in a 1150 kg cavity-type receiver with Nb-1 Zr bayonet-type tubes and LiF as the PCM; its thermal behavior was found to be satisfactory on the basis of numerical simulation. K.K.

**A89-41444\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**DENSITIES OF SOME MOLTEN FLUORIDE SALT MIXTURES SUITABLE FOR HEAT STORAGE IN SPACE POWER APPLICATIONS**

AJAY K. MISRA (NASA, Lewis Research Center, Cleveland, OH) *Electrochemical Society, Journal* (ISSN 0013-4651), vol. 135, Nov. 1988, p. 2780, 2781. refs  
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Liquid densities were determined for a number of fluoride salt mixtures suitable for heat storage in space power applications, using a procedure that consisted of measuring the loss of weight of an inert bob in the melt. The density apparatus was calibrated with pure LiF and NaF at different temperatures. Density data for safe binary and ternary fluoride salt eutectics and congruently melting intermediate compounds are presented. In addition, a comparison was made between the volumetric heat storage capacity of different salt mixtures. I.S.

**A89-43224# ANALYTICAL SIMULATION OF LIQUID SLUG FORMATION IN A HEAT PIPE WITH MULTI-HEAT LOAD**

TETSURO OHGUSHI (Mitsubishi Electric Corp., Central Research Laboratory, Amagasaki, Japan) and YASUSHI SAKURAI (Mitsubishi Electric Corp., Kamakura, Japan) *AIAA, Thermophysics Conference*, 24th, Buffalo, NY, June 12-14, 1989, 7 p. refs (AIAA PAPER 89-1708) Copyright

This paper describes analysis of liquid slug formation in a heat pipe under zero gravity. The analysis is based on a situation where multiple heat loads are imposed on a heat pipe as seen in a heat pipe network of a current spacecraft which has many high heat dissipating electronics. The analysis includes prediction of location, length of liquid slug and dryout limit of heat pipe with multiple heat loads counting those effects. The analysis was compared with experimental results and good agreement was confirmed.

Author

**A89-43633 SOLAR ARRAY MECHANISMS FOR INDIAN SATELLITES, APPLE, IRS AND INSAT-1T5**

SAMIRAN DAS (ISRO, Vikram Sarabhai Space Centre, Trivandrum, India) and I. SELVARAJ (ISRO, Satellite Centre, Bangalore, India) *Space Power* (ISSN 0951-5089), vol. 7, no. 3-4, 1988, p. 247-260.

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Large area rigid panel deployable and trackable solar arrays are widely used in present-day operational satellites. Three solar array mechanisms of this type for Indian spacecraft are described, one of which has already undergone flight verification. The other two mechanisms are of higher complexity and being readied for launch in the immediate future, as essential for providing India's space services in communication and remote sensing fields. Design approach, test program and implications of test modeling toward achieving the design goal are discussed. Performance characteristics of the solar array mechanisms achieved after flight verification and qualification tests are also highlighted in the paper. Author

**A89-45803\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.  
**POWER SYSTEMS FOR PRODUCTION, CONSTRUCTION, LIFE SUPPORT, AND OPERATIONS IN SPACE**

RONALD J. SOVIE (NASA, Lewis Research Center, Cleveland, OH) IN: *Engineering, construction, and operations in space: Proceedings of the Space '88 Conference*, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 928-939. Previously announced in STAR as N88-21254.

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As one looks to man's future in space it becomes obvious that unprecedented amounts of power are required for the exploration, colonization, and exploitation of space. Activities envisioned include interplanetary travel and LEO to GEO transport using electric propulsion, earth and lunar observatories, advance space station, free-flying manufacturing platforms, communications platforms, and eventually evolutionary lunar and Mars bases. These latter bases would start as camps with modest power requirements (kWes) and evolve to large bases as manufacturing, food production, and life support materials are developed from lunar raw materials. These latter activities require very robust power supplies (MWes). The advanced power system technologies being pursued by NASA to fulfill these future needs are described. Technologies discussed will include nuclear, photovoltaic, and solar dynamic space power systems, including energy storage, power conditioning, power transmission, and thermal management. The state-of-the-art and gains to be made by technology advancements will be discussed. Mission requirements for a variety of applications (LEO, GEO, lunar, and Martian) will be treated, and data for power systems ranging from a few kilowatts to megawatt power systems will be represented. In addition the space power technologies being initiated under NASA's new Civilian Space Technology Initiative (CSTI) and Space Leadership Planning Group Activities will be discussed. Author

**A89-45805\* Remtech, Inc., Huntsville, AL.  
SOLAR WATER HEATER FOR NASA'S SPACE STATION**

RICHARD E. SOMERS and R. DANIEL HAYNES (Remtech, Inc., Huntsville, AL) IN: *Engineering, construction, and operations in space: Proceedings of the Space '88 Conference*, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 952-963. Research supported by NASA. Copyright

The feasibility of using a solar water heater for NASA's Space Station is investigated using computer codes developed to model the Space Station configuration, orbit, and heating systems. Numerous orbit variations, system options, and geometries for the collector were analyzed. Results show that a solar water heater, which would provide 100 percent of the design heating load and would not impose a significant impact on the Space Station overall design is feasible. A heat pipe or pumped fluid radial plate collector of about 10-sq m, placed on top of the habitat module was found to be well suited for satisfying water demand of the Space Station. Due to the relatively small area required by a radial plate, a concentrator is unnecessary. The system would use only 7 to 10 percent as much electricity as an electric water-heating system. I.S.

**A89-46202 A STATISTICAL STUDY OF POWER SUPPLY RELIABILITY. I**  
THOMAS M. KOWALSKY (Control Data Corp., Minneapolis, MN) IN: *Institute of Environmental Sciences, Annual Technical Meeting*, 34th, King of Prussia, PA, May 3-5, 1988, Proceedings. Mount Prospect, IL, Institute of Environmental Sciences, 1988, p. 12-19. Copyright

The environmental production screening of an airborne power supply is discussed. Two sample populations of failures were studied: one taken before the implementation of a comprehensive corrective action program and one taken after the program. The times-to-failure from both samples are analyzed using Weibull/Bayesian methods. It is found that the populations of failure all fit a bimodal Weibull distribution. The graphical parameters before and after the implementation of the program are compared to determine the characteristics which could be used to detect improvements in product performance and to quantitatively evaluate the effectiveness of the corrective action. R.B.



## A89-46206

**A STATISTICAL STUDY OF POWER SUPPLY RELIABILITY. II**  
 THOMAS M. KOWALSKY (Control Data Corp., Minneapolis, MN)  
 IN: Institute of Environmental Sciences, Annual Technical Meeting,  
 34th, King of Prussia, PA, May 3-5, 1988, Proceedings. Mount  
 Prospect, IL, Institute of Environmental Sciences, 1988, p. 39-48.  
 refs

Copyright

The failure histories of an airborne power supply is examined using environment production screening of two samples from before and after the implementation of a comprehensive corrective action program. The multiple censoring abilities of hazard analysis are used to depict the distributions of the main component and design problems which contributed to the failures. Plots of component failures before and after the corrective action are presented for the power diodes, the chopper circuit, and unverified position.

R.B.

## A89-46509

**ICOSP '89; IAF INTERNATIONAL CONFERENCE ON SPACE POWER, CLEVELAND, OH, JUNE 5-7, 1989, PAPERS**

Conference sponsored by IAF. Space Power (ISSN 0951-5089), vol. 8, no. 1-2 & 3, 1989, p. Vol. 8, no. 1-2, 256 p.; vol. 8, no. 3, 170 p. For individual items see A89-46510 to A89-46536.

Copyright

The conference presents papers on solar photovoltaic systems and technology, nuclear space power systems, energy storage, and solar dynamic power for space. Other topics include nuclear space power technologies, advanced solar space power systems, and advanced nuclear space power systems concepts. Consideration is also given to reliability and single point failure design issues in thermionic space nuclear power systems and a high specific power aneutronic space reactor.

K.K.

## A89-46510

**PHOTOVOLTAIC SPACE POWER HISTORY AND PERSPECTIVE**

E. L. RALPH (Hughes Aircraft Co., Los Angeles, CA) (IAF, International Conference on Space Power, Cleveland, OH, June 5-7, 1989) Space Power (ISSN 0951-5089), vol. 8, no. 1-2, 1989, p. 3-10.

(IAF PAPER ICOSP89-1-1) Copyright

Photovoltaic space power systems have been the preferred technology for most spacecraft missions. This is due to a combination of factors. Of primary importance is the high reliability afforded by the large redundant matrix of solid state photovoltaic devices that make up a solar array. Of course, the low cost of a solar power system relative to the complete spacecraft is also an important factor. Progress over the past 30 years has continually improved the conversion efficiencies, decreased system weights, and reduced costs, so that alternate technologies always have a moving target to surpass if they are to be competitive. This paper describes the progress that has been made and some advances that are likely to be achieved in the future.

Author

## A89-46511

**LARGE SOLAR ARRAY DESIGN**

GARY F. TURNER and STEPHEN C. DEBROCK (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) (IAF, International Conference on Space Power, Cleveland, OH, June 5-7, 1989) Space Power (ISSN 0951-5089), vol. 8, no. 1-2, 1989, p. 11-22.

(IAF PAPER ICOSP89-1-2) Copyright

Developments forming the foundation for the current Space Station Freedom Solar Array and platform designs and for two operational satellite programs are discussed. Particular attention is given to the basic design concept for large area solar arrays as well as concept evolution and hardware development, the current Space Station Freedom design, and solar array manufacturing. The Space Station solar array consists of eight solar array wings which support a 75 Kw bus with a 187.2 Kw power output at the four-year design point.

K.K.

## A89-46512

**GALLIUM ARSENIDE TECHNOLOGIES IN PHOTOVOLTAIC CONVERSION**

P. A. ILES, Y. C. M. YEH, and F. HO (Applied Solar Energy Corp., City of Industry, CA) (IAF, International Conference on Space Power, Cleveland, OH, June 5-7, 1989) Space Power (ISSN 0951-5089), vol. 8, no. 1-2, 1989, p. 23-29.

(IAF PAPER ICOSP89-1-5) Copyright

This paper describes how GaAs technology has been applied to manufacture high efficiency solar cells for use on spacecraft. Improved substrates, layer growth and cell fabrication processes have been combined to demonstrate that GaAs cells can provide some attractive options for spacecraft power designers and can be supplied at the required production levels. To penetrate this highly conservative market has required steady development for about ten years, and this development work is demonstrating promise for wider use of GaAs-based cells.

Author

**A89-46513\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**ADVANCES IN THIN-FILM SOLAR CELLS FOR LIGHTWEIGHT SPACE PHOTOVOLTAIC POWER**

GEOFFREY A. LANDIS, SHEILA G. BAILEY, and DENNIS J. FLOOD (NASA, Lewis Research Center, Cleveland, OH) (IAF, International Conference on Space Power, Cleveland, OH, June 5-7, 1989) Space Power (ISSN 0951-5089), vol. 8, no. 1-2, 1989, p. 31-50. refs

(IAF PAPER ICOSP89-1-6) Copyright

The development of photovoltaic arrays beyond the next generation is discussed with attention given to the potentials of thin-film polycrystalline and amorphous cells. Of particular importance is the efficiency (the fraction of incident solar energy converted to electricity) and specific power (power to weight ratio). It is found that the radiation tolerance of thin-film materials is far greater than that of single crystal materials. CuInSe<sub>2</sub> shows no degradation when exposed to 1-MeV electrons.

K.K.

## A89-46514

**HIGH VOLTAGE SOLAR ARRAY INTERACTING WITH IONOSPHERIC PLASMA**

H. KUNINAKA, K. KURIKI (Institute of Space and Astronautical Science, Sagamihara, Japan), and Y. NOZAKI (IAF, International Conference on Space Power, Cleveland, OH, June 5-7, 1989) Space Power (ISSN 0951-5089), vol. 8, no. 1-2, 1989, p. 51-68. Research supported by the Japanese Society for the Promotion of Science. refs

(IAF PAPER ICOSP89-1-9) Copyright

A scaling model is used to study the interference phenomena on the high-voltage solar array near the ionospheric plasma. These phenomena are estimated quantitatively for the two-dimensional high-voltage (2D/HV) solar array experiment aboard Japan's space flyer unit (SFU). The 2D/HV system consists of a deployable array and solar cells which are furnished on a small part of the two-dimensional array with restriction of the SFU resources. The arrangement of the solar cells on the two-dimensional array is determined.

K.K.

## A89-46515

**SPACE POWER THERMAL ENERGY STORAGE - PLANNED EXPERIMENTS FOR PHASE CHANGE MATERIAL TESTS IN MICROGRAVITY**

S. WEINGARTNER, J. BLUMENBERG (Muenchen, Technische Universität, Munich, Federal Republic of Germany), and F. LINDNER (DLR, Institut fuer technische Thermodynamik, Stuttgart, Federal Republic of Germany) (IAF, International Conference on Space Power, Cleveland, OH, June 5-7, 1989) Space Power (ISSN 0951-5089), vol. 8, no. 1-2, 1989, p. 63-66. refs

(IAF PAPER ICOSP89-3-2) Copyright

Drop tower experiments, ballistic flight experiments, and a Spacelab experiment (D2-mission, scheduled for December 1991) are reviewed in an attempt to evaluate all microgravity induced phenomena influencing the performance and lifetime of the heat of fusion storage. Problems and solutions associated with thermal

energy storage (TES) applications in space are discussed as well as the relevance of microgravity to TES. All three experiments are shown to be cost-effective. K.K.

**AB9-46517\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

#### **SOLAR DYNAMIC POWER FOR SPACE STATION FREEDOM**

THOMAS L. LABUS, RICHARD R. SECUNDE (NASA, Lewis Research Center, Cleveland, OH), and RONALD G. LOVELY (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) (IAF, International Conference on Space Power, Cleveland, OH, June 5-7, 1989) Space Power (ISSN 0951-5089), vol. 8, no. 1-2, 1989, p. 97-114. Previously announced in STAR as N89-23516. refs

(IAF PAPER ICOSP89-4-1) Copyright

The Space Station Freedom Program is presently planned to consist of two phases. At the completion of Phase 1, Freedom's manned base will consist of a transverse boom with attached manned modules and 75 kW of available electric power supplied by photovoltaic (PV) power sources. In Phase 2, electric power available to the manned base will be increased to 125 kW by the addition of two solar dynamic (SD) power modules, one at each end of the transverse boom. Power for manned base growth beyond Phase 2 will be supplied by additional SD modules. Studies show that SD power for the growth era will result in life cycle cost savings of \$3 to \$4 billion when compared to PV-supplied power. In the SD power modules for Space Station Freedom, an offset parabolic concentrator collects and focuses solar energy into a heat receiver. To allow full power operation over the entire orbit, the receiver includes integral thermal energy storage by means of the heat of fusion of a salt mixture. Thermal energy is removed from the receiver and converted to electrical energy by a power conversion unit (PCU) which includes a closed Brayton cycle (CBC) heat engine and an alternator. The receiver/PCU/radiator combination will be completely assembled and charged with gas and cooling fluid on earth before launch to orbit. The concentrator subassemblies will be pre-aligned and stowed in the orbiter bay before launch. On orbit, the receiver/PCU/radiator assembly will be installed as a unit. The pre-aligned concentrator panels will then be latched together and the total concentrator attached to the receiver/PCU/radiator by the astronauts. After final electric connections are made and checkout is complete, the SD power module will be ready for operation. Author

**AB9-46518**

#### **NERVA-DERIVATIVE REACTOR TECHNOLOGY - A NATIONAL ASSET FOR DIVERSE SPACE POWER APPLICATIONS**

J. F. WETT, J. W. H. OHL, and J. M. LIVINGSTON (Westinghouse Electric Corp., Advanced Energy Systems Dept., Madison, PA) (IAF, International Conference on Space Power, Cleveland, OH, June 5-7, 1989) Space Power (ISSN 0951-5089), vol. 8, no. 1-2, 1989, p. 115-124.

(Contract DE-AC07-88ID-12752)

(IAF PAPER ICOSP89-5-3) Copyright

A description of the NERVA-derivative reactor and the space power systems is presented for a wide range of applications and space missions. The NDR is a zirconium hydride (ZrH) and graphite-moderated reactor; with ZrH moderation, the NDR has a low critical mass of 9 kg. The NDR fuel element is described with attention given to the support element; redundant diverse engineered safety features; and redundant inherent passive nuclear safety capabilities. It is shown that, with little change in the basic design, the NDR can provide a power source for steady-state electric power, direct thermal propulsion, bimodal power and dual mode propulsion power, and a power source for extraterrestrial basing. K.K.

**AB9-46519**

#### **THE FUTURE OF CLOSED BRAYTON CYCLE SPACE POWER SYSTEMS**

WILLIAM B. HARPER, JR., ANTHONY PIETSCH, and WILLIAM G. BAGGENSTOSS (Allied-Signal Aerospace Co., Fluid Systems Div., Tempe, AZ) (IAF, International Conference on Space Power,

Cleveland, OH, June 5-7, 1989) Space Power (ISSN 0951-5089), vol. 8, no. 1-2, 1989, p. 125-136. refs

(IAF PAPER ICOSP89-5-4) Copyright

The background and current status of closed Brayton cycle (CBC) power conversion systems for space applications are discussed. The CBC has the following features: high efficiency at modest power levels, ability to operate using a very wide range of fuels, and high heat rejection temperatures which are ideal for cogeneration. The use of CBC systems for both the Space Station Freedom solar dynamic power module and the dynamic isotope power system is discussed. K.K.

**AB9-46520\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

#### **FREE-PISTON STIRLING TECHNOLOGY FOR SPACE POWER**

JACK G. SLABY (NASA, Lewis Research Center, Cleveland, OH) (IAF, International Conference on Space Power, Cleveland, OH, June 5-7, 1989) Space Power (ISSN 0951-5089), vol. 8, no. 1-2, 1989, p. 137-147. Previously announced in STAR as N89-20194. refs

(IAF PAPER ICOSP89-5-7) Copyright

An overview is presented of the NASA Lewis Research Center free-piston Stirling engine activities directed toward space power. This work is being carried out under NASA's new Civil Space Technology Initiative (CSTI). The overall goal of CSTI's High Capacity Power element is to develop the technology base needed to meet the long duration, high capacity power requirements for future NASA space missions. The Stirling cycle offers an attractive power conversion concept for space power needs. Discussed here is the completion of the Space Power Demonstrator Engine (SPDE) testing culminating in the generation of 25 kW of engine power from a dynamically-balanced opposed-piston Stirling engine at a temperature ratio of 2.0. Engine efficiency was approximately 22 percent. The SPDE recently has been divided into two separate single-cylinder engines, called Space Power Research Engine (SPRE), that now serve as test beds for the evaluation of key technology disciplines. These disciplines include hydrodynamic gas bearings, high-efficiency linear alternators, space qualified heat pipe heat exchangers, oscillating flow code validation, and engine loss understanding. Author

**AB9-46521**

#### **CONSIDERATIONS OF POWER CONVERSION TECHNIQUES IN FUTURE SPACE APPLICATIONS**

PRAVEEN JAIN, J. BOTTRILL, and M. TANJU (Canadian Astronautics, Ltd., Space Systems Group, Ottawa, Canada) (IAF, International Conference on Space Power, Cleveland, OH, June 5-7, 1989) Space Power (ISSN 0951-5089), vol. 8, no. 1-2, 1989, p. 149-177. refs

(IAF PAPER ICOSP89-6-5) Copyright

Advanced concepts of dc/ac, dc/dc, and ac/dc power conversion for high power space applications are presented. For high power applications, the resonant mode converters offer high efficiency, low mass and volume, reduced EMI, and high reliability. For dc/ac power conversion, parallel, series-parallel and hybrid resonant inverter configurations are presented. For dc/dc power conversion, the pulse width modulated series, parallel, and series-parallel resonant topologies are presented. For ac/dc power conversion, the paper presents two new converter configurations which convert high-frequency ac voltage to controlled dc voltage through the use of a single conversion stage and which draw close to sinusoidal current with a near unity power factor. K.K.

**AB9-46522**

#### **CENTRAL-STATION ELECTRIC POWER FOR SPACECRAFT**

LUCIEN DESCHAMPS (Electricite de France, Clamart) and JERRY GREY (IAF, International Conference on Space Power, Cleveland, OH, June 5-7, 1989) Space Power (ISSN 0951-5089), vol. 8, no. 1-2, 1989, p. 179-196. refs

(IAF PAPER ICOSP89-7-4) Copyright

Central-station electric power for spacecraft has been explored conceptually for over two decades as a solution to the economic delivery of high power levels over long periods of time. However,

all spacecraft designs to date have been based on the use of onboard supplies - solar, nuclear, and chemical - because the total space power demand has not yet reached the levels at which dedicated space power depots would be economically viable. Nevertheless, the growth in projected power demand for the next several decades could warrant the use of such dedicated space-based powerplants. This paper examines and assesses the various technological options for space power generation and transmission and the system considerations associated with the space-based central-power-station concept. **Author**

**A89-46714\*** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

#### **APSA - A NEW GENERATION OF PHOTOVOLTAIC SOLAR ARRAYS**

P. M. STELLA (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) and R. M. KURLAND (TRW, Inc., Space and Technology Group, Redondo Beach, CA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989, 8 p.  
(AIAA PAPER 89-2271) Copyright

This paper provides details on the Advanced Photovoltaic Solar Array (APSA) wing design, fabrication, and testing. The impact of array size change on performance and mechanical characteristics is discussed. Projections for future performance enhancements that may be expected through use of advanced solar cells presently under development are examined. **C.D.**

**A89-47440\***

#### **THE INTERACTION BETWEEN A POSITIVELY BIASED CONDUCTOR ON A HIGH VOLTAGE SOLAR ARRAY AND A PLASMA**

DANIEL E. HASTINGS (MIT, Cambridge, MA) IN: International Electric Propulsion Conference, 20th, Garmisch-Partenkirchen, Federal Republic of Germany, Oct. 3-6, 1988, Proceedings, Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1988, p. 115-120. refs

The physics of a positively biased conductor surrounded by dielectrics in contact with plasma is investigated. It is shown that due to the presence of secondary emission from the surrounding dielectrics the voltage of the surfaces near the conductor can be bistable. One of the bistable solutions always has very low secondary emission while the other has high secondary emission. The secondary current emitted from the neighboring dielectrics is collected by the conductor. When the voltage on the dielectric undergoes a transition from one bistable solution to another this will be seen as a concomitant increase in the current collected to the conductor. A theoretical treatment is presented for a conductor surrounded by dielectrics such as silicon dioxide. The theory is applied to explain the 'snapover' effect. The snapover effect is observed on high voltage solar arrays which involve the use of highly biased surfaces in contact with the space environment. It has been observed that when such surfaces are positively biased that the current undergoes an anomalous increase at a critical voltage. **Author**

**A89-48957\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

#### **COMPATIBILITY OF MOLTEN SALTS WITH ADVANCED SOLAR DYNAMIC RECEIVER MATERIALS**

D. A. JAWORSKE (NASA, Lewis Research Center, Cleveland, OH) and W. D. PERRY (Auburn University, AL) AIAA, Thermophysics Conference, 24th, Buffalo, NY, June 12-14, 1989, 7 p. refs  
(AIAA PAPER 89-1756) Copyright

Metal-coated graphite fibers are being considered as a thermal conductivity enhancement filler material for molten salts in solar dynamic thermal energy storage systems. The successful metal coating chosen for this application must exhibit acceptable wettability and must be compatible with the molten salt environment. Contact angle values between molten lithium fluoride and several metal, metal fluoride, and metal oxide substrates have been determined at 892 C using a modification of the Wilhelmy

plate technique. Reproducible contact angles with repeated exposure to the molten LF indicated compatibility. **Author**

**A89-50471**

#### **A 20 KHZ HYBRID RESONANT POWER SOURCE FOR THE SPACE STATION**

PRAVEEN K. JAIN and M. CELAL TANUJ (Canadian Astronautics, Ltd., Space Systems Group, Ottawa, Canada) (IEE, International Conference on Power Electronics and Variable-Speed Drives, 3rd, London, England, July 1988) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251), vol. 25, July 1989, p. 491-496.  
Copyright

A hybrid resonant inverter system is presented that satisfies the steady-state operating requirements of a power source for the proposed International Space Station mobile servicing system. The steady-state behavior of the inverter was analyzed, and a method is described for optimizing the design of the resonant network. Performance characteristics such as the total harmonic distortion of the output voltage, the RMS output voltage, and the inverter efficiency are presented. The hybrid resonant inverter system maintains an excellent efficiency over varying output-load demand. **I.E.**

**A89-51282\***

#### **DEVELOPMENT OF SLIPRINGS FOR SPACECRAFT APPLICATION**

V. R. SAMBAMORTHY (ISRO, Satellite Centre, Bangalore, India) and P. M. VARGHESE (ISRO, Vikram Sarabhai Space Centre, Trivandrum, India) IN: National Conference on Industrial Tribology, Trivandrum, India, Jan. 19, 20, 1989, Proceedings, Volume 1, Trivandrum, India, Vikram Sarabhai Space Centre, 1989, p. VI-2.1 to VI-2.6. refs

Sliprings for satellite solar arrays consist of electrical sliding contacts made of ring and brush combinations, with the brush sliding on the ring. Mechanical performance demands low frictional torque, minimum wear-out and debris formation, for continuous operation under high space vacuum and temperature extremes for a period of seven to ten years of satellite life. Different designs are presented based on material selection, lubrication system, debris management, wear-out characteristics, frictional torque, qualification for deep space application, precautions in storage, and test philosophy followed in the development and qualification of a slipring for the IRS spacecraft. **C.E.**

**A89-51845**

#### **POWER GALORE IN SPACE**

LUCIEN DESCHAMPS (Electricite de France, Direction des Etudes et Recherches, Clamart, France) IN: Space commerce; Proceedings of the Second International Conference and Exhibition on the Commercial and Industrial Uses of Outer Space, Montreux, Switzerland, Feb. 21-25, 1988, New York, Gordon and Breach Science Publishers, 1988, p. 211-225. refs  
Copyright

Future developments in space activities depend on the use of powerful and reliable power sources. This paper discusses the technology available at present and that which will be available in the near future. It considers the near- and medium-term growth of power levels for different classes of satellites and space stations. It looks also at longer-term prospects for low-orbit platforms and solar power satellites in geostationary orbit. These tentative forecasts are combined to provide a global assessment of the evolution of energy needs of future space systems. **Author**

**A89-52203\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

#### **SPACE SOLAR CELL RESEARCH**

DENNIS J. FLOOD (NASA, Lewis Research Center, Cleveland, OH) Chemical Engineering Progress (ISSN 0360-7275), April 1989, p. 62-67.  
Copyright

A brief overview is given of the scope of the NASA space solar cell research and development program. Silicon cells, gallium



arsenide cells, indium phosphide cells, and superlattice solar cells are addressed, indicating the state of the art of each type in outer space and their advantages and drawbacks for use in outer space. Contrasts between efficiency in space and on earth are pointed out. C.D.

**A89-53258#**

**RADIATIVE COOLING OF A LIQUID DROPLET-GAS LAYER**

Y. BAYAZITOGLU and P. D. JONES (Rice University, Houston, TX) IN: ASME 1988 National Heat Transfer Conference, Houston, TX, July 24-27, 1988, Proceedings, Volume 1, New York, American Society of Mechanical Engineers, 1988, p. 193-199. refs  
Copyright

The present work is an analysis of a layer of liquid droplets surrounded by vapor, acting as a medium for heat rejection to space by radiation. This combined radiation and conduction problem was solved using spherical harmonic methods to approximate the radiation transfer equation. The resulting heat flow solution defines heat rejection capabilities in cases where the presence of gas surrounding the droplets cannot be neglected. Author

**A89-53275\*#** University of South Florida, Tampa.

**LATENT ENERGY STORAGE WITH SALT AND METAL MIXTURES FOR SOLAR DYNAMIC APPLICATIONS**

R. A. CRANE and K. S. KONSTANTINOU (South Florida, University, Tampa, FL) IN: ASME 1988 National Heat Transfer Conference, Houston, TX, July 24-27, 1988, Proceedings, Volume 1, New York, American Society of Mechanical Engineers, 1988, p. 705-710. Research supported by NASA. refs  
Copyright

This paper examines three design alternatives for the development of a solar dynamic heat receiver as applied to power systems operating in low earth orbit. These include a base line design used for comparison in ongoing NASA studies, a system incorporating a salt energy storage system with the salt dispersed within a metal mesh and a hybrid system incorporating both a molten salt and molten metal for energy storage. Based on a typical low earth orbit condition, designs are developed and compared to determine the effect of resultant conductivity, heat capacity and heat of fusion on system size, weight, temperature gradients, cycle turbine inlet temperature and material utilization. Author

**A89-53324\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**THIN FILM COATINGS FOR SPACE ELECTRICAL POWER SYSTEM APPLICATIONS**

DANIEL A. GIULINO (NASA, Lewis Research Center, Cleveland, OH) IN: Surface modification technologies II; Proceedings of the Second International Conference, Chicago, IL, Sept. 26-28, 1988. Warrendale, PA, Minerals, Metals and Materials Society, 1989, p. 73-90. Previously announced in STAR as N88-28966. refs  
Copyright

This paper examines some of the ways in which thin film coatings can play a role in aerospace applications. Space systems discussed include photovoltaic and solar dynamic electric power generation systems, including applications in environmental protection, thermal energy storage, and radiator emittance enhancement. Potential applications of diamondlike films to both atmospheric and space based systems are examined. Also, potential uses of thin films of the recently discovered high-temperature superconductive materials are discussed. Author

**A89-53325#**

**SP-100 REACTOR FLIGHT EXPERIMENT SUPPORT STUDIES**

MICHAEL J. SCHULLER, DAVID W. CONLEY, and DONALD A. VERRILL (USAF, Weapons Laboratory, Kirtland AFB, NM) AIAA, ASME, SAE, and ASCE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-12, 1989, 8 p.  
(AIAA PAPER 89-2582)

This paper describes three major projects undertaken in fiscal

year 89 in support of the SP-100 Reactor Flight Experiment (RFE). The Master Schedule Definition Study aims at identifying all of the major activities necessary to complete the RFE and to set ground rules for RFE. The Launch Vehicle Integration Study will quantify the mission capabilities of low cost, expendable RFE launch vehicles. The Qualification and Acceptance Testing Study will identify options for qualifying space reactor power systems. C.D.

**N89-20194\*#** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**FREE-PISTON STIRLING TECHNOLOGY FOR SPACE POWER**

JACK G. SLABY 1989 21 p. Prepared for presentation at the International Conference on Space Power, Cleveland, OH, 5-7 Jun. 1989; sponsored in part by the International Astronautical Federation (NASA-TM-101956; E-4653; NAS 1.15:101956) Avail: NTIS HC A03/MF A01 CSCL 10/2

An overview is presented of the NASA Lewis Research Center free-piston Stirling engine activities directed toward space power. This work is being carried out under NASA's new Civil Space Technology Initiative (CSTI). The overall goal of CSTI's High Capacity Power element is to develop the technology base needed to meet the long duration, high capacity power requirements for future NASA space missions. The Stirling cycle offers an attractive power conversion concept for space power needs. Discussed here is the completion of the Space Power Demonstrator Engine (SPDE) testing-culminating in the generation of 75 kW of engine power from a dynamically-balanced opposed-piston Stirling engine at a temperature ratio of 2.0. Engine efficiency was approximately 22 percent. The SPDE recently has been divided into two separate single-cylinder engines, called Space Power Research Engine (SPRE), that now serve as test beds for the evaluation of key technology disciplines. These disciplines include hydrodynamic gas bearings, high-efficiency linear alternators, space qualified heat pipe heat exchangers, oscillating flow code validation, and engine loss understanding. Author

**N89-22651\*#** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**THE NASA SPACE SOLAR CELL ADVANCED RESEARCH PROGRAM**

DENNIS J. FLOOD 1989 9 p. Presented at International PVSEC-4, Sydney, Australia, 14-17 Feb. 1989; sponsored by The Institution of Radio and Electronics Engineers of Australia and the Univ. of New South Wales (NASA-TM-102020; E-4747; NAS 1.15:102020) Avail: NTIS HC A02/MF A01 CSCL 10/1

Two major requirements for space solar cells are high efficiency and survivability in the naturally occurring charged particle space radiation environment. Performance limits for silicon space cells are well understood. Advanced cells using GaAs and InP are under development to provide significantly improved capability for the future. Author

**N89-22653\*#** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**NUMERICAL MODEL OF SOLAR DYNAMIC RADIATOR FOR PARAMETRIC ANALYSIS**

JENNIFER L. RHATIGAN 1989 10 p. Prepared for presentation at the 24th Intersociety Energy Conversion Engineering Conference, Washington, DC, 6-11 Aug. 1989; sponsored in part by IEEE, AIAA, ASME, SAE, and ASCE (NASA-TM-102054; E-4807; NAS 1.15:102054) Avail: NTIS HC A02/MF A01 CSCL 21/8

Growth power requirements for Space Station Freedom will be met through addition of 25 kW solar dynamic (SD) power modules. The SD module rejects waste heat from the power conversion cycle to space through a pumped-loop, multi-panel, deployable radiator. The baseline radiator configuration was defined during the Space Station conceptual design phase and is a function of the state point and heat rejection requirements of the power conversion unit. Requirements determined by the overall station

design such as mass, system redundancy, micrometeoroid and space debris impact survivability, launch packaging, costs, and thermal and structural interaction with other station components have also been design drivers for the radiator configuration. Extensive thermal and power cycle modeling capabilities have been developed which are powerful tools in Station design and analysis, but which prove cumbersome and costly for simple component preliminary design studies. In order to aid in refining the SD radiator to the mature design stage, a simple and flexible numerical model was developed. The model simulates heat transfer and fluid flow performance of the radiator and calculates area mass and impact survivability for many combinations of flow tube and panel configurations, fluid and material properties, and environmental and cycle variations. A brief description and discussion of the numerical model, its capabilities and limitations, and results of the parametric studies performed is presented. *Author*

**N89-22755#** New Energy Development Organization, Tokyo (Japan).

**TECHNICAL FEASIBILITY STUDY ON THE DEVELOPMENT OF CERAMIC THERMOELECTRIC CONVERSION, PART 2**  
May 1988 78 p. In ENGLISH and JAPANESE  
(DE88-756481; NEDCJ-P-8708-PT-2) Avail: NTIS (US Sales Only) HC A05/MF A01

A survey was conducted on the current trends and problems with ceramic thermoelectric conversion, which converts thermal energy directly to the electric energy. The conversion efficiency of 19 percent and the output density of more than 0.5W/sq cm have been accomplished in the laboratory. A possible application is the space power source. The Jet Propulsion Laboratory has been conducting the conceptual design. Present tasks include the development of electrodes with high output density and durability and construction of modular structures. The Ford has developed a 100 W class module with 6 single cells, which is under testing. The application of ceramic thermoelectric conversion will be widely advanced and the R and D will be accelerated when its advantages are demonstrated with modular structures in aspects of meeting the diversified energy needs and developing clean energy source. *DOE*

**N89-22980\*#** Space Power, Inc., San Jose, CA.  
**MEGAWATT CLASS NUCLEAR SPACE POWER SYSTEMS (MCNPS) CONCEPTUAL DESIGN AND EVALUATION REPORT, VOLUME 3, TECHNOLOGIES 2: POWER CONVERSION Final Report**

J. R. WETCH et al. Sep. 1988 136 p.  
(Contract NAS3-23867)  
(NASA-CR-179614-VOL-3; NAS 1.26:179614-VOL-3; SPI-25-1-VOL-3) Avail: NTIS HC A07/MF A01 CSCL 10/2

The major power conversion concepts considered for the Megawatt Class Nuclear Space Power System (MCNPS) are discussed. These concepts include: (1) Rankine alkali-metal-vapor turbine alternators; (2) in-core thermionic conversion; (3) Brayton gas turbine alternators; and (4) free piston Stirling engine linear alternators. Considerations important to the coupling of these four conversion alternatives to an appropriate nuclear reactor heat source are examined along with the comparative performance characteristics of the combined systems meeting MCNPS requirements. *M.G.*

**N89-22981\*#** Space Power, Inc., San Jose, CA.  
**MEGAWATT CLASS NUCLEAR SPACE POWER SYSTEMS (MCNPS) CONCEPTUAL DESIGN AND EVALUATION REPORT, VOLUME 2, TECHNOLOGIES 1: REACTORS, HEAT TRANSPORT, INTEGRATION ISSUES Final Report**

J. R. WETCH et al. Sep. 1988 143 p.  
(Contract NAS3-23867)  
(NASA-CR-179614-VOL-2; NAS 1.26:179614-VOL-2; SPI-25-1-VOL-2) Avail: NTIS HC A07/MF A01 CSCL 10/2

The objectives of the Megawatt Class Nuclear Space Power System (MCNPS) study are summarized and candidate systems and subsystems are described. Particular emphasis is given to

the heat rejection system and the space reactor subsystem.

*Author*

**N89-23006\*#** Eagle-Picher Industries, Inc., Joplin, MO.  
**MULTI-MISSION Ni-H2 BATTERY CELL FOR THE 1990'S Abstract Only**

LEE MILLER, JACK BRILL, and GARY DOODSON. In NASA, Lewis Research Center, Space Electrochemical Research and Technology Conference: Abstracts p 33 1989  
Avail: NTIS HC A03/MF A01 CSCL 10/1

A sufficient production, test and operational database is now available to permit design technology optimization for the next decade. The evolved battery cell design features standardized technology intended to support multiple type missions (e.g., both GEO and LEO). Design analyses and validation test cells demonstrate improved performance plus attractive specific-energy characteristics will be achieved. *Author*

**N89-23357\*#** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.  
**COMPARISON OF SOLAR PHOTOVOLTAIC AND NUCLEAR REACTOR POWER SYSTEMS FOR A HUMAN-TENDED LUNAR OBSERVATORY**

J. M. HICKMAN and H. S. BLOOMFIELD 1989 7 p. Proposed for presentation at the 24th Intersociety Energy Conversion Engineering Conference, Washington, DC, 6-11 Aug. 1989; sponsored by IEEE, AIAA, ANS, ASME, SAE, ACS and AIChE (NASA-TM-102015; E-4729; NAS 1.15:102015) Avail: NTIS HC A02/MF A01 CSCL 03/2

Photovoltaic and nuclear surface power systems were examined at the 20 to 100 kW power level range for use at a human-tended lunar astronomical observatory, and estimates of the power system masses were made. One system, consisting of an SP-100 thermoelectric nuclear power supply integrated with a lunar lander, is recommended for further study due to its low system mass, potential for modular growth, and applicability to other surface power missions, particularly in the Martian system. *Author*

**N89-23516\*#** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**SOLAR DYNAMIC POWER FOR SPACE STATION FREEDOM**  
THOMAS L. LABUS, RICHARD R. SECORDE, and RONALD G. LOVELY (Rockwell International Corp., Canoga Park, CA.) 1989 24 p. Presented at the International Conference on Space Power, Cleveland, OH, 5-7 Jun. 1989; sponsored by the International Astronautical Federation  
(NASA-TM-102016; E-4730; NAS 1.15:102016) Avail: NTIS HC A03/MF A01 CSCL 22/2

The Space Station Freedom Program is presently planned to consist of two phases. At the completion of Phase 1, Freedom's manned base will consist of a transverse boom with attached manned modules and 75 kW of available electric power supplied by photovoltaic (PV) power sources. In Phase 2, electric power available to the manned base will be increased to 125 kW by the addition of two solar dynamic (SD) power modules, one at each end of the transverse boom. Power for manned base growth beyond Phase 2 will be supplied by additional SD modules. Studies show that SD power for the growth era will result in life cycle cost savings of \$3 to \$4 billion when compared to PV-supplied power. In the SD power modules for Space Station Freedom, an offset parabolic concentrator collects and focuses solar energy into a heat receiver. To allow full power operation over the entire orbit, the receiver includes integral thermal energy storage by means of the heat of fusion of a salt mixture. Thermal energy is removed from the receiver and converted to electrical energy by a power conversion unit (PCU) which includes a closed Brayton cycle (CBC) heat engine and an alternator. The receiver/PCU/radiator combination will be completely assembled and charged with gas and cooling fluid on Earth before launch to orbit. The concentrator subassemblies will be pre-aligned and stowed in the orbiter bay before launch. On orbit, the receiver/PCU/radiator assembly will be installed as a unit. The pre-aligned concentrator panels will then be latched together and the total concentrator attached to

the receiver/PCU/radiator by the astronauts. After final electric connections are made and checkout is complete, the SD power module will be ready for operation. Author

**N89-23909\*** Honeywell, Inc., Phoenix, AZ. Satellite Systems Div.

#### **SIGNAL AND POWER ROLL RING TESTING UPDATE**

DENNIS W. SMITH in NASA, Marshall Space Flight Center, The 23rd Aerospace Mechanisms Symposium p 255-266 Mar. 1989 Avail: NTIS HC A15/MF A02 CSCL 20/11

The development of the roll ring as a long-life, low-torque alternative to the slip ring is discussed. A roll ring consists of one or more circular flexures captured by their own spring force in the annular space between two concentric conductors or contact rings. The advantages of roll rings over other types of electrical transfer devices are: extremely low drag torque, high transfer efficiencies in high-power configurations, extremely low wear debris generation, long life, and low weight for high-power applications. Author

**N89-23979\*** Aerospatiale, Cannes (France).

#### **THE THIRD GENERATION RIGID SOLAR ARRAY GSR3**

A. MAMODE, D. GANGLOFF (Centre National d'Etudes Spatiales, Toulouse, France), J. L. BASTARD, and PH. AUFRAY Paris, France 1988 7 p (REPT-882-440-105; ETN-89-94498) Avail: NTIS HC A02/MF A01

A solar array design, which is well suited to future missions is described. It combines high performance to cost ratio and reliability, thanks to a very simple design. The prototype model is detailed. It is characterized by deployment mechanisms of a new type, modularity, versatility and high performance levels. It is selected as a suitable candidate for Spacebus, SPOT4, and Vesta projects. ESA

**N89-24416\*** National Aeronautics and Space Administration, Washington, DC.

#### **THE SPACE STATION POWER SYSTEM**

1989 12 p Original document contains color illustrations (NASA-TM-101245; NAS 1.15:101245) Avail: NTIS HC A03/MF A01 CSCL 22/2

The requirements for electrical power by the proposed Space Station Freedom are discussed. The options currently under consideration are examined. The three power options are photovoltaic, solar dynamic, and a hybrid system. Advantages and disadvantages of each system are tabulated. Drawings and artist concepts of the Space Station configuration are provided. Author

**N89-24418\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

#### **REVIEW OF THE ENVIRONMENTAL EFFECTS OF THE SPACE STATION FREEDOM PHOTOVOLTAIC POWER MODULE**

HENRY K. NAHRA 1989 8 p Proposed for presentation at the 24th Intersociety Energy Conversion Engineering Conference, Washington, DC, 6-11 Aug. 1989; sponsored by IEEE, AIAA, ANS, ASME, SAE, ACS and AICHE (NASA-TM-102076; E-4836; NAS 1.15:102076) Avail: NTIS HC A02/MF A01 CSCL 22/2

An overview is provided of the environment in the low Earth orbit (LEO), the interaction of this environment with the Photovoltaic (PV) Power system of the Space Station Freedom is reviewed, and the environmental programs are described that are designed to investigate the interactions of the LEO environment with the photovoltaic power system. Such programs will support and impact the design of the subsystems of the PV module in order to survive the design lifetime in the LEO natural and induced environment. Author

**N89-24427\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

#### **ENERGY STORAGE AND THERMAL CONTROL SYSTEM DESIGN STATUS**

STEPHEN N. SIMONS, BRYAN C. WILLHOITE, and GERT

VANOMMERING (Ford Aerospace and Communications Corp., Palo Alto, CA) 1989 8 p Presented at the 24th Intersociety Energy Conversion Engineering Conference, Washington, DC, 6-11 Aug. 1989; cosponsored by the IEEE, AIAA, ANS, ASME, SAE, ACS and AICHE (NASA-TM-102136; E-4933; NAS 1.15:102136) Avail: NTIS HC A02/MF A01 CSCL 22/2

The Space Station Freedom electric power system (EPS) will initially rely on photovoltaics for power generation and Ni/H<sub>2</sub> batteries for electrical energy storage. The current design for and the development status of two major subsystems in the PV Power Module is discussed. The energy storage subsystem comprised of high capacity Ni/H<sub>2</sub> batteries and the single-phase thermal control system that rejects the excess heat generated by the batteries and other components associated with power generation and storage is described. Author

**N89-24434\*** Martin Marietta Aerospace, Denver, CO. Denver Astronautics Group.

#### **SPACE STATION AUTOMATION OF COMMON MODULE POWER MANAGEMENT AND DISTRIBUTION Interim Final Report**

W. MILLER, E. JONES, B. ASHWORTH, J. RIEDESEL, C. MYERS, K. FREEMAN, D. STEELE, R. PALMER, R. WALSH, J. GOHRING et al. Feb. 1989 572 p (Contract NAS6-36433)

(NASA-CR-183607; NAS 1.26:183607; MCR-89-516) Avail: NTIS HC A24/MF A03 CSCL 21/8

A history and description of the work performed in defining, designing, and developing the Space Station Module Power Management and Distribution System (SSM/PMAD) breadboard, complete with software is given. The hardware architecture is described along with its associated deterministic software architecture, the Artificial Intelligence (AI) systems architecture, and the methodology and process of the overall system integration. The automation system was built upon a 20 kHz ac source with redundancy of the power buses. There are two power distribution control units which furnish power to six load centers which in turn enable load circuits based upon a system generated schedule. The system possesses the capability to perform diagnosis whenever a distribution fault is encountered. The system autonomously reconfigures its operation during run-time to reschedule activities around the fault, rather than performing a system halt. A.D.

**N89-24438\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

#### **CONCENTRATION OF OFF-AXIS RADIATION BY SOLAR CONCENTRATORS FOR SPACE POWER**

KENT S. JEFFERIES 1989 10 p Proposed for presentation at the 24th Intersociety Energy Conversion Engineering Conference, Washington, DC, 6-11 Aug. 1989; sponsored by IEEE, AIAA, ANS, ASME, SAE, ACS and AICHE (NASA-TM-102052; E-4804; NAS 1.15:102052) Avail: NTIS HC A02/MF A01 CSCL 10/1

Off-axis radiation is radiation from any direction not parallel to the axis of the solar concentrator. It will be reflected to regions other than the focus of the parabolic concentrator and possibly concentrated there. Four types of off-axis radiation are discussed. These are: (1) small off-axis angles during walk-off; (2) large off-axis angles; (3) an extended off-axis source such as Earth albedo; and (4) miscellaneous off-axis sources including radio frequency sources and local point sources. A previous analytical study used a computer code named PIXEL to predict concentration of off-axis radiation and a previous experimental study used an 11-m diameter multifaceted dish concentrator to validate the PIXEL analysis. The PIXEL code was limited in that it represented concentration by an ideal parabolic reflector of light from a point source. Another code named OFFSET has been developed to represent the solar concentrator being developed for Space Station Freedom. It is a detailed, ray tracing model which represents 50 ray originating points on the Sun and reflections from 10 points on each of the 456 concentrator facets. Results of this code are generally similar



to the PIXEL results although there are small differences due to the more detailed representations of the Sun and concentrator that were used in the OFFSET code. Author

**N89-24439\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**SPACE STATION FREEDOM ELECTRICAL POWER SYSTEM  
HARDWARE COMMONALITY WITH THE UNITED STATES  
POLAR PLATFORM**

LORRA L. RIEKER and FRANCIS M. HARABURDA 1989  
11 p Presented at the 24th Intersociety Energy Conversion  
Engineering Conference, Washington, DC, 6-11 Aug. 1989;  
cosponsored by the IEEE, AIAA, ANS, ASME, SAE, ACS and  
AIChE  
(NASA-TM-102074; E-4833; NAS 1.15:102074) Avail: NTIS HC  
A03/MF A01 CSCL 09/3

The National Aeronautics and Space Administration has adopted the policy to achieve the maximum practical level of commonality for the Space Station Freedom program in order to significantly reduce life cycle costs. Commonality means using identical or similar hardware/software for meeting common sets of functionality similar requirements. Information on how the concept of commonality is being implemented with respect to electric power system hardware for the Space Station Freedom and the U.S. Polar Platform is presented. Included is a historical account of the candidate common items which have the potential to serve the same power system functions on both Freedom and the Polar Platform. Author

**N89-24442#** Aerospatiale, Cannes (France).

**SPACE PHOTOVOLTAIC TECHNIQUE. STATE OF THE ART,  
TRENDS (PHOTOVOLTAIQUE SPATIAL: ETAT DE L'ART,  
TENDANCES)**

M. ZILIANI and L. PELENC Nov. 1988 13 p In FRENCH  
Presented at the Agence Francaise pour la Maitrise de l'Energie  
Seminaire d'Evaluation des Conventions et Contrats de Recherche  
Conversion Photovoltaïque  
(REPT-882-440-120; ETN-89-94513) Avail: NTIS HC A03/MF  
A01

Photovoltaic power systems currently used in satellites are reviewed. The solar panels for Meteosat, SPOT, TDF, and GSR3 are shown. The solar cells used for space application are described. The trends discussed show the expansion of the AsGa cells and an ever increasing spacecraft power demand. ESA

**N89-24448\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**SPACE STATION FREEDOM SOLAR ARRAY DESIGN  
DEVELOPMENT**

CINDY WINSLOW, KEVIN BILGER (Lockheed Missiles and Space Co., Sunnyvale, CA), and COSMO R. BARAONA 1989 6 p  
Presented at the 24th Intersociety Energy Conversion Engineering  
Conference, Washington, DC, 6-11 Aug. 1989; cosponsored by  
the IEEE, AIAA, ANS, ASME, SAE, ACS and AIChE  
(Contract NAS3-25062)  
(NASA-TM-102105; E-4871; NAS 1.15:102105) Avail: NTIS HC  
A02/MF A01 CSCL 10/2

The Space Station Freedom Solar Array Program is required to provide a 75 kW power module that uses eight solar array (SA) wings over a four-year period in low Earth orbit (LEO). Each wing will be capable of providing 23.4 kW at the 4-year design point. Lockheed Missiles and Space Company, Inc. (LMSC) is providing the flexible substrate SAs that must survive exposure to the space environment, including atomic oxygen, for an operating life of fifteen years. Trade studies and development testing, important for evolving any design to maturity, are presently underway at LMSC on the flexible solar array. The trade study and development areas being investigated include solar cell module size, solar cell weld pads, panel stiffener frames, materials inherently resistant to atomic oxygen, and weight reduction design alternatives. Author

**N89-24704\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**SPACE PHOTOVOLTAIC RESEARCH AND TECHNOLOGY,  
1988. HIGH EFFICIENCY, SPACE ENVIRONMENT, AND  
ARRAY TECHNOLOGY**

Washington Apr. 1989 362 p Conference held in Cleveland,  
OH, 19-21 Apr. 1988  
(NASA-CP-3030; E-4587; NAS 1.55:3030) Avail: NTIS HC  
A16/MF A03 CSCL 10/1

The 9th Space Photovoltaic Research and Technology conference was held at the NASA Lewis Research Center from April 19 to 21, 1988. The papers and workshop summaries report remarkable progress on a wide variety of approaches in space photovoltaics, for both near and far term applications. Among the former is the recently developed high efficiency GaAs/Ge cell, which formed the focus of a workshop discussion on heterojunction cells. Still aimed at the long term, but with a significant payoff in a new mission capability, are InP cells, with their potentially dramatic improvement in radiation resistance. Approaches to near term, array specific powers exceeding 130 W/kg are also reported, and advanced concentrator panel technology with the potential to achieve over 250 W/sq m is beginning to take shape.

**N89-24708\*** Air Force Aero Propulsion Lab., Wright-Patterson AFB, OH.

**SPACE POWER TECHNOLOGY 21: PHOTOVOLTAICS**

JOSEPH WISE In NASA, Lewis Research Center, Space  
Photovoltaic Research and Technology, 1988. High Efficiency,  
Space Environment, and Array Technology p 10-15 Apr. 1989  
Avail: NTIS HC A16/MF A03 CSCL 10/1

The Space Power needs for the 21st Century and the program in photovoltaics needed to achieve it are discussed. Workshops were conducted in eight different power disciplines involving industry and other government agencies. The Photovoltaics Workshop was conducted at Aerospace Corporation in June 1987. The major findings and recommended program from this workshop are discussed. The major finding is that a survivable solar power capability is needed in photovoltaics for critical Department of Defense missions including Air Force and Strategic Defense Initiative. The tasks needed to realize this capability are described in technical, not financial, terms. The second finding is the need for lightweight, moderately survivable planar solar arrays. High efficiency thin III-V solar cells can meet some of these requirements. Higher efficiency, longer life solar cells are needed for application to both future planar and concentrator arrays with usable life up to 10 years. Increasing threats are also anticipated and means for avoiding prolonged exposure, retraction, maneuvering and autonomous operation are discussed. Author

**N89-24707\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**PROGRESS IN INDIUM PHOSPHIDE SOLAR CELL RESEARCH  
IRVING WEINBERG, CLIFFORD K. SWARTZ, and R. E. HART,  
JR. In its Space Photovoltaic Research and Technology, 1988.  
High Efficiency, Space Environment, and Array Technology p 19-27  
Apr. 1989**

Avail: NTIS HC A16/MF A03 CSCL 10/1

Progress, dating from the start of the Lewis program, is reviewed emphasizing processing techniques which have achieved the highest efficiencies in a given year. To date, the most significant achievement has been attainment of AM0 total area efficiencies approaching 19 percent. Although closed tube diffusion is not considered to be an optimum process, reasonably efficient 2cm x 2cm and 1cm x 2cm InP cells have been produced in quantity by this method with a satellite to be launched in 1990 using these cells. Proton irradiation of these relatively large area cells indicates radiation resistance comparable to that previously reported for smaller InP cells. A similar result is found for the initial proton irradiations of ITO/InP cells processed by D. C. sputtering. With respect to computer modeling, a comparison of n/p homojunction InP and GaAs cells of identical geometries and dopant concentrations has confirmed the superior radiation resistance of InP cells under 1 MeV electron irradiations. Author

**N89-24715\*** TRW Space Technology Labs., Redondo Beach, CA.

# **THE IMPACT OF SOLAR CELL TECHNOLOGY ON PLANAR SOLAR ARRAY PERFORMANCE**

MICHAEL W. MILLS and RICHARD M. KURLAND *In NASA, Lewis Research Center, Space Photovoltaic Research and Technology, 1988. High Efficiency, Space Environment, and Array Technology p 111-121 Apr. 1989*  
 Avail: NTIS HC A16/MF A03 CSCL 10/1

The results of a study into the potential impact of advanced solar cell technologies on the characteristics (weight, cost, area) of typical planar solar arrays designed for low, medium and geosynchronous altitude earth orbits are discussed. The study considered planar solar array substrate designs of lightweight, rigid-panel graphite epoxy and ultra-lightweight Kapton. The study proposed to answer the following questions: Do improved cell characteristics translate into array-level weight, size and cost improvements? What is the relative importance of cell efficiency, weight and cost with respect to array-level performance? How does mission orbital environment affect array-level performance. Comparisons were made at the array level including all mechanisms, hinges, booms, and harnesses. Array designs were sized to provide 5kW of array power (not spacecraft bus power, which is system dependent but can be scaled from given values). The study used important grass roots issues such as use of the GaAs radiation damage coefficients as determined by Anspaugh. Detailed costing was prepared, including cell and cover costs, and manufacturing attrition rates for the various cell types.

Author

**N89-24716\*** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

# **ADVANCED PHOTOVOLTAIC SOLAR ARRAY DEVELOPMENT**

RICHARD M. KURLAND (TRW Space Technology Labs., Redondo Beach, CA.) and PAUL STELLA *In NASA, Lewis Research Center, Space Photovoltaic Research and Technology, 1988. High Efficiency, Space Environment, and Array Technology p 122-137 Apr. 1989*

Avail: NTIS HC A16/MF A03 CSCL 10/1  
 Phase 2 of the Advanced Photovoltaic Solar Array (APSA) program, started in mid-1987, is currently in progress to fabricate prototype wing hardware that will lead to wing integration and testing in 1989. The design configuration and key details are reviewed. A status of prototype hardware fabricated to date is provided. Results from key component-level tests are discussed. Revised estimates of array-level performance as a function of solar cell device technology for geosynchronous missions are given.

Author

**N89-24720\*** Energy Conversion Devices, Inc., Troy, MI. Sonovics Solar Systems, Inc.

# **DEPLOYABLE AEROSPACE PV ARRAY BASED ON AMORPHOUS SILICON ALLOYS**

JOSEPH J. HANAK, LEE WALTER, DAVID DOBIAS, and HARVEY FLAISHER *In its Space Photovoltaic Research and Technology, 1988. High Efficiency, Space Environment, and Array Technology p 162-163 Apr. 1989* Sponsored in part by Defense Nuclear Agency

Avail: NTIS HC A16/MF A03 CSCL 10/1  
 The development of the first commercial, ultralight, flexible, deployable, PV array for aerospace applications is discussed. It is based on thin-film, amorphous silicon alloy, multijunction, solar cells deposited on a thin metal or polymer by a proprietary, roll-to-roll process. The array generates over 200 W at AM0 and is made of 20 giant cells, each 54 cm x 29 cm (1566 sq cm in area). Each cell is protected with bypass diodes. Fully encapsulated array blanket and the deployment mechanism weigh about 800 and 500 g, respectively. These data yield power per area ratio of over 60 W/sq m specific power of over 250 W/kg (4 kg/kW) for the blanket and 154 W/kg (6.5 kg/kW) for the power system. When stowed, the array is rolled up to a diameter of 7 cm and a length of 1.1 m. It is deployed quickly to its full area of 2.92 m x 1.1 m, for instant power. Potential applications include power for

lightweight space vehicles, high altitude balloons, remotely piloted and tethered vehicles. These developments signal the dawning of a new age of lightweight, deployable, low-cost space arrays in the range from tens to tens of thousands of watts for near-term applications and the feasibility of multi-100 kW to MW arrays for future needs.

Author

**N89-24730\*** Applied Solar Energy Corp., City of Industry, CA.

# **FLEXIBILITY IN SPACE SOLAR CELL PRODUCTION**

SCOTT KHEMTHONG and PETER A. ILES *In NASA, Lewis Research Center, Space Photovoltaic Research and Technology, 1988. High Efficiency, Space Environment, and Array Technology p 272-276 Apr. 1989*

Avail: NTIS HC A16/MF A03 CSCL 10/1

The wide range of cells that must be available from present-day production lines for space solar cells are described. After over thirty years of space-cell use, there is very little standardization in solar cell design. It is not generally recognized what a wide range of designs must remain available on cell production lines. This range of designs is surveyed.

Author

**N89-24731\*** Spectrolab, Inc., Sylmar, CA.

# **GALLIUM ARSENIDE WELDED PANEL TECHNOLOGY FOR ADVANCED SPACEFLIGHT APPLICATIONS**

D. R. LILLINGTON, M. S. GILLANDERS, G. F. J. GARLICK, B. T. CAVICCHI, G. S. GLENN, and S. P. TOBIN (Spire Corp., Bedford, MA.) *In NASA, Lewis Research Center, Space Photovoltaic Research and Technology, 1988. High Efficiency, Space Environment, and Array Technology p 277-285 Apr. 1989*

Avail: NTIS HC A16/MF A03 CSCL 10/1

A significant impediment to the widespread use of GaAs solar cells in space is the cost and weight of the GaAs substrate. In order to overcome these problems, Spectrolab is pursuing thin cell technologies encompassing both liquid phase epitaxy (LPE) GaAs on GaAs and MOCVD GaAs on Ge cells. Spectrolab's experience in the manufacture of 4 to 6 mil 2 cm x 4 cm GaAs cells on a LPE production line is discussed. By thinning the cells at a late state of processing, production yields comparable to 12 mil cells have been achieved. Data are presented showing that GaAs cells can be welded without degradation and have achieved minimum average efficiencies of 18 percent AM0, 28 C with efficiencies up to 20 percent. Spectrolab, in conjunction with Spire Corporation has also been pursuing GaAs on Ge cell technology in support of larger area lighter weight power systems. Data are presented showing that individual 2 cm x 2 cm, 6 mil cell efficiencies up to 21.7 percent have been achieved. Efficiencies up to 24 percent AM0 will be possible by optimizing the GaAs/Ge interface. Cells have been welded without degradation using silver interconnects and have been laid down on an aluminum honeycomb/graphite facesheet substrate to produce a small coupon. The efficiency was 18.1 percent at AM0, 28 C.

Author

**N89-24732\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

# **DOMED FRESNEL LENS CONCENTRATOR TECHNOLOGY FOR SPACE APPLICATION**

MICHAEL F. PISZCZOR, JR. and MARK J. ONEILL (ENTECH Corp., Dallas-Fort Worth Airport, TX.) *In its Space Photovoltaic Research and Technology, 1988. High Efficiency, Space Environment, and Array Technology p 286-291 Apr. 1989*

Avail: NTIS HC A16/MF A03 CSCL 10/1

Over the past three years, NASA Lewis and Entech, Inc. have been investigating the use of high efficiency refractive photovoltaic concentrators for use in space. The design currently under investigation uses a square domed Fresnel lens to focus light on a GaAs concentrator cell. A prismatic cell cover, which directs light away from the front contacts and thus eliminates metalization losses, is applied to the top of the GaAs cell to further enhance array efficiency. The latest experimental results based on testing the GaAs cell/prism cover assembly at standard and operating conditions are presented.

Author

**N89-24733\*#** Varian Associates, Palo Alto, CA.  
**THE 25 PERCENT-EFFICIENT GAAS CASSEGRAINIAN CONCENTRATOR CELL**

H. C. HAMAKER, M. GROUTNER, N. R. KAMINAR, M. S. KURYLA, M. J. LADLE, D. D. LIU, H. F. MACMILLAN, L. D. PARTAIN, G. F. VIRSHUP, J. G. WERTHEN et al. In NASA, Lewis Research Center, Space Photovoltaic Research and Technology, 1988. High Efficiency, Space Environment, and Array Technology p 292-297 Apr. 1989 Prepared in cooperation with Sandia National Labs., Albuquerque, NM

Avail: NTIS HC A16/MF A03 CSCL 10/1

Very high-efficiency GaAs Cassegrainian solar cells have been fabricated in both the n-p and p-n configurations. The n-p configuration exhibits the highest efficiency at concentration, the best cells having an efficiency  $\eta$  of 24.5 percent (100X, AM0, temperature  $T = 28$  C). Although the cells are designed for operation at this concentration, peak efficiency is observed near 300 suns ( $\eta = 25.1$  percent). To our knowledge, this is the highest reported solar cell efficiency for space applications. The improvement in efficiency over that reported at the previous SPRAT conference is attributed primarily to lower series resistance and improved grid-line plating procedures. Using previously measured temperature coefficients, researchers estimate that the n-p GaAs cells should deliver approximately 22.5 percent efficiency at the operating conditions of 100 suns and  $T = 80$  C. This performance exceeds the NASA program goal of 22 percent for the Cassegrainian cell. One hundred Cassegrainian cells have been sent to NASA as deliverables, sixty-eight in the n-p configuration and thirty-two in the p-n configuration. Author

**N89-24736\*#** Midwest Research Inst., Golden, CO. Solar Energy Research Inst.

**AMO EFFICIENCY MEASUREMENTS**

KEITH EMERY and CARL OSTERWALD In NASA, Lewis Research Center, Space Photovoltaic Research and Technology, 1988. High Efficiency, Space Environment, and Array Technology p 323-331 Apr. 1989

Avail: NTIS HC A16/MF A03 CSCL 10/1

Procedures for measuring the air mass zero (AM0) current versus voltage characteristics and calculating the efficiency are discussed. The various factors influencing the determination of the efficiency include the I-V measurement system, reference cell calibration, standard reporting conditions, area measurement, light source characteristics, temperature measurement and control, and the measurement procedures. Each of these sources contributes to the precision index and bias limit which is combined to obtain the total uncertainty in the efficiency. These factors are discussed as well as how to minimize differences in the reported AM0 efficiency of a given PV cell between various laboratories. Author

**N89-25267\*#** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**PROTOFLIGHT PHOTOVOLTAIC POWER MODULE**

**SYSTEM-LEVEL TESTS IN THE SPACE POWER FACILITY**

JUAN C. RIVERA and LUKE A. KIRCH Aug. 1989 21 p Presented at the 24th Intersociety Energy Conversion Engineering Conference, Washington, DC, 6-11 Aug. 1989; sponsored in part by IEEE, AIAA, ANS, ASME, SAE, ACS, and AICHE

(NASA-TM-102066; E-4823; NAS 1.15:102066) Avail: NTIS HC A03/MF A01 CSCL 22/2

Work Package Four, which includes the NASA-Lewis and Rocketdyne, has selected an approach for the Space Station Freedom Photovoltaic (PV) Power Module flight certification that combines system level qualification and acceptance testing in the thermal vacuum environment: The protoflight vehicle approach. This approach maximizes ground test verification to assure system level performance and to minimize risk of on-orbit failures. The preliminary plans for system level thermal vacuum environmental testing of the protoflight PV Power Module in the NASA-Lewis Space Power Facility (SPF), are addressed. Details of the facility modifications to refurbish SPF, after 13 years of downtime, are briefly discussed. The results of an evaluation of the effectiveness

of system level environmental testing in screening out incipient part and workmanship defects and unique failure modes are discussed. Preliminary test objectives, test hardware configurations, test support equipment, and operations are presented. Author

**N89-25269\*#** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**SOLAR DYNAMIC POWER MODULE DESIGN**

RICHARD R. SECUNDE, THOMAS L. LABUS, and RONALD G. LOVELY (Rockwell International Corp., Canoga Park, CA.) 1989 11 p Presented at the 24th Intersociety Energy Conversion Engineering Conference, Washington, DC, 6-11 Aug. 1989; cosponsored by the IEEE, AIAA, ANS, ASME, SAE, ACS and AICHE

(NASA-TM-102055; E-4808; NAS 1.15:102055) Avail: NTIS HC A03/MF A01 CSCL 10/2

Studies have shown that use of solar dynamic (SD) power for the growth eras of the Space Station Freedom program will result in life cycle cost savings when compared to power supplied by photovoltaic sources. In the SD power module, a concentrator collects and focuses solar energy into a heat receiver which has integral thermal energy storage. A power conversion unit (PCU) based on the closed Brayton thermodynamic cycle removes thermal energy from the receiver and converts that energy to electrical energy. Since the closed Brayton cycle is a single phase gas cycle, the conversion hardware (heat exchangers, turbine, compressor, etc.) can be designed for operation in low earth orbit, and tested with confidence in test facilities on earth before launch into space. The concentrator subassemblies will be aligned and the receiver/PCU/radiator combination completely assembled and charged with gas and cooling liquid on earth before launch to, and assembly on orbit. Author

**N89-25273\*#** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**SPACE STATION FREEDOM PHOTOVOLTAIC POWER MODULE DESIGN STATUS**

AMADOR P. JIMENEZ (Rockwell International Corp., Canoga Park, CA.) and MARK A. HOBRECHT 1989 6 p Presented at the 24th Intersociety Energy Conversion Engineering Conference, Washington, DC, 6-11 Aug. 1989; cosponsored by the IEEE, AIAA, ANS, ASME, SAE, ACS and AICHE

(NASA-TM-102073; E-4832; NAS 1.15:102073) Avail: NTIS HC A02/MF A01 CSCL 10/2

Electric power generation for Space Station Freedom will be provided by four photovoltaic (PV) power modules using silicon solar cells during Phase 1 operation. Each PV power module requires two solar arrays with 32,800 solar cells generating 18.75 kW of dc power for a total of 75 kW. A portion of this power will be stored in nickel-hydrogen batteries for use during eclipse, and the balance will be processed and converted to 20 kHz ac power for distribution to end users through the power management and distribution system. The design incorporates an optimized thermal control system, pointing and tracking provision with the application of gimbals, and the use of orbital replacement units (ORU's) to achieve modularization. Design status of the PV power module, as derived from major trade studies, is discussed at hardware levels ranging from component to system. Details of the design are presented where appropriate. Author

**N89-25275\*#** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**LAUNCH PACKAGING OPTIONS FOR THE PHOTOVOLTAIC POWER MODULE CARGO ELEMENT**

MARK A. HOBRECHT and SCOTT T. VOGT (Rockwell International Corp., Canoga Park, CA.) 1989 7 p Presented at the 24th Intersociety Energy Conversion Engineering Conference, Washington, DC, 6-11 Aug. 1989; cosponsored by the IEEE, AIAA, ANS, ASME, SAE, ACS and AICHE

(NASA-TM-102072; E-4831; NAS 1.15:102072) Avail: NTIS HC A02/MF A01 CSCL 10/1

The National Aeronautics and Space Administration recently embarked on the Space Station Freedom program, which will utilize



the Shuttle Orbiter for transportation to orbit. This task will be accomplished with a number of flights over several years. Each flight is unique in terms of the hardware that is manifested and the method by which it is integrated to form viable cargo elements. Work Package 4 is responsible for the electric power system for Space Station Freedom, and was delegated the authority to develop a photovoltaic (PV) power module cargo element. The PV power module consists of several unique assemblies. The first of these is the combined solar array/beta gimbal assembly. The remaining assemblies form the single combined integrated equipment assembly for each PV power module. These three combined assemblies are packaged into a launch cradle to form the PV power module cargo element, which is placed in the cargo bay of the Shuttle Orbiter for transportation to orbit. Various constraints determine the packaging options for the three PV power module combined assemblies. The size and shape of the combined assemblies in relation to the Shuttle Orbiter cargo bay dimensions and other manifested hardware are ultimately a factor in determining the acceptable packaging schemes for the PV power module cargo element. Several packaging options for the PV power module cargo element are presented. These options are discussed in terms of their impact on the overall flight hardware manifest as determined by the various constraints. NASA

**N89-25278\*** National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, AL.

**AN EVALUATION OF THE GENERAL DYNAMICS 20 KHZ 5 KW BREADBOARD FOR SPACE STATION ELECTRICAL POWER AT MSFC**

DAVID K. HALL and ROBERT E. KAPUSTKA May 1989 15 p (NASA-TM-100367; NAS 1.15:100367) Avail: NTIS HC A03/MF A01 CSCL 10/2

The results and observations are discussed of tests made on the General Dynamics 20 kHz Breadboard for Space Station Electrical Power. The General Dynamics 20 kHz system only is considered, and not the issue of the use of 20 kHz ac Power for Spacecraft Applications. Author

**N89-25280\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**ESTIMATED PERFORMANCE AND FUTURE POTENTIAL OF SOLAR DYNAMIC AND PHOTOVOLTAIC POWER SYSTEMS FOR SELECTED LEO AND HEO MISSIONS**

DAVID J. BENTS and CHENG Y. LU 1989 13 p Presented at the 24th Intersociety Energy Conversion Engineering Conference, Washington, DC, 6-11 Aug. 1989; cosponsored by the IEEE, AIAA, ANS, ASME, SAE, ACS and AIChE (NASA-TM-102083; E-4848; NAS 1.15:102083) Avail: NTIS HC A03/MF A01 CSCL 10/2

Solar Photo Voltaic (PV) and thermal dynamic power systems for application to selected Low Earth Orbit (LEO) and High Eccentric Orbit (Energy) (HEO) missions are characterized in the regime 7 to 35 kWe. Input parameters to the characterization are varied corresponding to anticipated introduction of improved or new technologies. Comparative assessment is made between the two power system types utilizing newly emerging technologies in cells and arrays, energy storage, optical surfaces, heat engines, thermal energy storage, and thermal management. The assessment is made to common ground rules and assumptions. The four missions (space station, sun-synchronous, Van Allen belt and GEO) are representative of the anticipated range of multi-kWe earth orbit missions. System characterizations include all required subsystems, including power conditioning, cabling, structure, to deliver electrical power to the user. Performance is estimated on the basis of three different levels of component technology: (1) state-of-art, (2) near-term, and (3) advanced technologies. These range from planar array silicon/IPV nickel hydrogen batteries and Brayton systems at 1000 K to thin film GaAs with high energy density secondary batteries or regenerative fuel cells and 1300 K Stirling systems with ultra-lightweight concentrators and radiators. The system estimates include design margin for performance degradations from the known environmental mechanisms (micrometeoroids and space debris, atomic oxygen, electron and proton flux) which are modeled

and applied depending on the mission. The results give expected performance, mass and drag of multi-kWe earth orbiting solar power systems and show how overall system figures of merit will improve as new component technologies are incorporated. Author

**N89-25282\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**CSTI HIGH CAPACITY POWER**

JERRY M. WINTER 1989 21 p Presented at the 24th Intersociety Energy Conversion Engineering Conference, Washington, DC, 6-11 Aug. 1989; cosponsored by the IEEE, AIAA, ANS, ASME, SAE, ACS and AIChE (NASA-TM-102059; E-4817; NAS 1.15:102059) Avail: NTIS HC A03/MF A01 CSCL 10/2

The SP-100 program was established in 1983 by DOD, DOE, and NASA as a joint program to develop the technology necessary for space nuclear power systems for military and civil application. During FY-86 and 87, the NASA SP-100 Advanced Technology Program was devised to maintain the momentum of promising technology advancement efforts started during Phase 1 of SP-100 and to strengthen, in key areas, the chances for successful development and growth capability of space nuclear reactor power systems for future space applications. In FY-88, the Advanced Technology Program was incorporated into NASA's new Civil Space Technology Initiative (CSTI). The CSTI Program was established to provide the foundation for technology development in automation and robotics, information, propulsion, and power. The CSTI High Capacity Power Program builds on the technology efforts of the SP-100 program, incorporates the previous NASA SP-100 Advanced Technology project, and provides a bridge to NASA Project Pathfinder. The elements of CSTI High Capacity Power development include Conversion Systems, Thermal Management, Power Management, System Diagnostics, and Environmental Interactions. Technology advancement in all areas, including materials, is required to assure the high reliability and 7 to 10 year lifetime demanded for future space nuclear power systems. The overall program will develop and demonstrate the technology base required to provide a wide range of modular power systems as well as allowing mission independence from solar and orbital altitude requirements. Several recent advancements in CSTI High Capacity power development will be discussed. Author

**N89-25403\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**DEVELOPMENT AND TESTING OF A 20-KHZ COMPONENT TEST BED**

ROBERT M. BUTTON, ANDREW S. BRUSH, and RICHARD C. SUNDBERG (General Dynamics Corp., San Diego, CA.) Aug. 1989 8 p Presented at the 24th Intersociety Energy Conversion Engineering Conference, Washington, DC, 6-11 Aug. 1989; sponsored in part by IEEE, AIAA, ANS, ASME, SAE, ACS, and AIChE

(Contract NAS3-25266)

(NASA-TM-102141; E-4940; NAS 1.15:102141) Avail: NTIS HC A02/MF A01 CSCL 09/3

A history of the General Dynamics Space Systems Division 20 kHz Breadboard is presented including its current configuration and its role in the Space Station Freedom (SSF) program. Highlights and results are presented on a series of tests conducted on the 20 kHz Breadboard. The first test presented is the 20 kHz Breadboard Acceptance test. This test verified the operation of the delivered Breadboard and also characterized the main components of the system. Next, an in-depth efficiency testing effort is presented. The tests attempted to apportion all the power losses in the 20 kHz Breadboard Main Invert Units. Distortion test data is presented showing the distortion characteristics of a Mapham inverter. Lastly, current work on the 20 kHz Breadboard is presented including Main Inverter Unit paralleling tests. Conclusions are summarized and references given. Author

**N89-25508\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**CHALLENGES FOR FUTURE SPACE POWER SYSTEMS**

HENRY W. BRANDHORST, JR. 1989 6 p Presented at the European Space Power Conference, Madrid, Spain, 2-6 Oct. 1989; sponsored by the ESA (NASA-TM-102063; E-4820; NAS 1.15:102063) Avail: NTIS HC A02/MF A01 CSCL 10/2

The future appears rich in missions that will extend the frontiers of knowledge, human presence in space, and opportunities for profitable commerce. The key to success of these ventures is the availability of plentiful, cost effective electric power and assured, low cost access to space. While forecasts of space power needs are problematic, an assessment of future needs based on terrestrial experience was made. These needs fall into three broad categories—survival, self sufficiency and industrialization. The cost of delivering payloads to orbital locations from low earth orbit (LEO) to Mars was determined and future launch cost reductions projected. From these factors, then, projections of the performance necessary for future solar and nuclear space power options were made. These goals are largely dependent upon orbital location and energy storage needs. Author

N89-25511# Argonne National Lab., IL.  
**MONOLITHIC SOLID OXIDE FUEL CELL DEVELOPMENT**  
K. M. MYLES and C. C. MCPHEETERS 1989 9 p Presented at the 2nd Space Electrochemical Research and Technology Conference, Cleveland, OH, 11 Apr. 1989 (Contract W-31-109-ENG-38) (DE89-010899; CONF-8904195-2) Avail: NTIS HC A02/MF A01

The feasibility of the monolithic solid oxide fuel cell (MSOFC) concept has been proven, and the performance has been dramatically improved. The differences in thermal expansion coefficients and firing shrinkages among the fuel cell materials have been minimized, thus allowing successful fabrication of the MSOFC with few defects. The MSOFC shows excellent promise for development into a practical power source for many applications from stationary power, to automobile propulsion, to space pulsed power. DOE

N89-28041# National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.  
**ADVANCES IN THIN-FILM SOLAR CELLS FOR LIGHTWEIGHT SPACE PHOTOVOLTAIC POWER**  
GEOFFREY A. LANDIS, SHEILA G. BAILEY, and DENNIS J. FLOOD 1989 29 p Presented at the International Conference on Space Power, Cleveland, OH, 5-7 Jun. 1989; sponsored by the International Astronautical Federation (NASA-TM-102017; E-4734; NAS 1.15:102017) Avail: NTIS HC A03/MF A01 CSCL 10/1

The present stature and current research directions of photovoltaic arrays as primary power systems for space are reviewed. There have recently been great advances in the technology of thin-film solar cells for terrestrial applications. In a thin-film solar cell the thickness of the active element is only a few microns; transfer of this technology to space arrays could result in ultralow-weight solar arrays with potentially large gains in specific power. Recent advances in thin-film solar cells are reviewed, including polycrystalline copper-indium selenide (CuInSe<sub>2</sub>) and related I-III-VI<sub>2</sub> compounds, polycrystalline cadmium telluride and related II-VI compounds, and amorphous silicon/hydrogen and alloys. The best experimental efficiency on thin-film solar cells to date is 12 percent AMO for CuIn Se<sub>2</sub>. This efficiency is likely to be increased in the next few years. The radiation tolerance of thin-film materials is far greater than that of single-crystal materials. CuIn Se<sub>2</sub> shows no degradation when exposed to 1 MeV electrons. Experimental evidence also suggests that most of all of the radiation damage on thin-films can be removed by a low temperature anneal. The possibility of thin-film multibandgap cascade solar cells is discussed, including the tradeoffs between monolithic and mechanically stacked cells. The best current efficiency for a cascade is 12.5 percent AMO for an amorphous silicon on CuInSe<sub>2</sub> multibandgap combination. Higher efficiencies are expected in the future. For several missions, including solar-electric propulsion, a manned Mars mission, and

lunar exploration and manufacturing, thin-film photovoltaic arrays may be a mission-enabling technology. Author

N89-28042# Texas A&M Univ., College Station. Power System Automation Lab.  
**ADVANCED POWER SYSTEM PROTECTION AND INCIDENT FAULT DETECTION AND PROTECTION OF SPACEBORNE POWER SYSTEMS Final Report**  
B. DON RUSSELL May 1989 159 p (Contract NAG9-14?) (NASA-CR-185330; JSC10-86-8483; NAS 1.26:185330) Avail: NTIS HC A08/MF A01 CSCL 10/2

This research concentrated on the application of advanced signal processing, expert system, and digital technologies for the detection and control of low grade, incipient faults on spaceborne power systems. The researchers have considerable experience in the application of advanced digital technologies and the protection of terrestrial power systems. This experience was used in the current contracts to develop new approaches for protecting the electrical distribution system in spaceborne applications. The project was divided into three distinct areas: (1) investigate the applicability of fault detection algorithms developed for terrestrial power systems to the detection of faults in spaceborne systems; (2) investigate the digital hardware and architectures required to monitor and control spaceborne power systems with full capability to implement new detection and diagnostic algorithms; and (3) develop a real-time expert operating system for implementing diagnostic and protection algorithms. Significant progress has been made in each of the above areas. Several terrestrial fault detection algorithms were modified to better adapt to spaceborne power system environments. Several digital architectures were developed and evaluated in light of the fault detection algorithms. Author

N89-28043# Jet Propulsion Lab., California Inst. of Tech., Pasadena.  
**SOLAR CELL RADIATION HANDBOOK. ADDENDUM 1: 1982-1988**  
BRUCE E. ANSPAUGH 15 Feb. 1989 47 p (Contract NAS7-918) (NASA-CR-185495; JPL-PUBL-82-69-ADD-1; NAS 1.26:185495) Avail: NTIS HC A03/MF A01 CSCL 10/2

The Solar Cell Radiation Handbook (JPL Publication 82-69) is updated. In order to maintain currency of solar cell radiation data, recent solar cell designs have been acquired, irradiated with 1 MeV electrons, and measured. The results of these radiation experiments are reported. Author

N89-28045# National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.  
**SPACE STATION FREEDOM POWER MANAGEMENT AND DISTRIBUTION SYSTEM DESIGN**  
FRED TERN 1989 10 p Prepared for presentation at the 40th Congress of the International Astronautical Federation, Malaga, Spain, 8-14 Oct. 1989 (NASA-TM-102283; E-4950; NAS 1.15:102283) Avail: NTIS HC A02/MF A01 CSCL 21/8

The design is described of the Space Station Freedom Power Management and Distribution (PMAD) System. In addition, the significant trade studies which were conducted are described, which led to the current PMAD system configuration. Author

N89-28177# National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.  
**COMPARATIVE THERMAL ANALYSIS OF THE SPACE STATION FREEDOM PHOTOVOLTAIC DEPLOYABLE BOOM STRUCTURE USING TRASYS, NEVADA, AND SINDA PROGRAMS**  
JOSEPH F. BAUMEISTER (Analox Corp., Cleveland, OH), DUANE E. BEACH, and SASAN C. ARMAND Jul. 1989 10 p Presented at the 19th Intersociety Conference on Environmental Systems, San Diego, CA, 24-26 Jul. 1989; sponsored in part by the Society of Automotive Engineers

(NASA-TM-102062; E-4819; NAS 1.15:102062) Avail: NTIS HC A02/MF A01 CSCL 20/4

The proposed Space Station Photovoltaic Deployable Boom was analyzed for operating temperatures. The boom glass/epoxy structure design needs protective shielding from environmental degradation. The protective shielding optical properties (solar absorptivity and emissivity) dictate the operating temperatures of the boom components. The Space Station Boom protective shielding must also withstand the effects of the extendible/retractable coiling action within the mast canister. A thermal analysis method was developed for the Space Station Deployable Boom to predict transient temperatures for a variety of surface properties. The modeling procedures used to evaluate temperatures within the boom structure incorporated the TRASYS, NEVADA, and SINDA thermal analysis programs. Use of these programs led to a comparison between TRASYS and NEVADA analysis methods. Comparing TRASYS and NEVADA results exposed differences in the environmental solar flux predictions.

Author

**N89-26292\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

#### ON-ORBIT RESULTS OF THE LIPS 3/INP HOMOJUNCTION SOLAR CELL EXPERIMENT

DAVID J. BRINKER 1989 7 p Presented at the European Space Power Conference, Madrid, Spain, 2-6 Oct. 1989; sponsored by the ESA

(NASA-TM-102131; E-4921; NAS 1.15:102131) Avail: NTIS HC A02/MF A01 CSCL 10/1

The flight performance of NASA Lewis Research Center's indium phosphide homojunction solar cell module on the LIPS 3 satellite is presented. A module of four n+p cells was fabricated and has been on-orbit on the LIPS 3 spacecraft since 1987. The experimental objective is the measurement of InP cell performance in the natural radiation environment of the 1100 kilometer altitude, 60 deg inclination, circular orbit. Flight data from the first year is near expected values, with no degradation in short-circuit current. The temperature dependence of current-voltage parameters is included along with the laboratory radiation tolerance studies necessary for normalization and analysis of the data. Details of the cell structure and flight module design are also discussed.

Author

**N89-26293\*** AstroSystems International, Inc., Newark, DE. AstroPower Div.

#### THE GAASP TOP SOLAR CELLS FOR INCREASED SOLAR CONVERSION EFFICIENCY Final Report, Jun. 1985 - Sep. 1988

JAMES B. MCNEELY, GERALD H. NEGLEY, and ALLEN M. BARNETT Jan. 1989 49 p

(Contract F33615-86-C-2605; AF PROJ. 3005)

(AD-A206808; AFWAL-TR-88-2120) Avail: NTIS HC A03/MF A01 CSCL 10/2

The development of multijunction solar cells is the key to achieving large increases in solar power conversion efficiency over current state-of-the-art technology. In the optimal multijunction design, the top solar cell is the most critical since, by itself, it generates two-thirds of the total power generated by the solar cell stack. There are two viable technical approaches for the top solar cell for the mechanically-stacked tandem solar cell: GaAsP/GaP and AlGaAs/AlGaAs. Both top solar cell approaches have demonstrated good device properties. No other approach has made acceptable devices.

GFA

**N89-26781\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

#### COMPARISON OF CONCEPTUAL DESIGNS FOR 25 KWE ADVANCED STIRLING CONVERSION SYSTEMS FOR DISH ELECTRIC APPLICATION Final Report

RICHARD K. SHALTENS and JEFFREY G. SCHREIBER 1989 16 p Prepared for presentation at the 24th Intersociety Energy Conversion Engineering Conference, Washington, DC, 6-11 Aug. 1989; sponsored in part by IEEE, AIAA, ANS, ASME, SAE, ACS,

and AIChE

(Contract DE-AT04-85AL-33408)

(NASA-TM-102085; E-4806; DOE/NASA/33408-3; NAS 1.15:102085) Avail: NTIS HC A03/MF A01 CSCL 10/2

The Advanced Stirling Conversion System (ASCS) Project is managed by NASA Lewis Research Center through a cooperative interagency agreement with DOE. Conceptual designs for the ASCS's were completed under parallel contracts in 1987 by Mechanical Technology Inc. (MTI) of Latham, NY, and Stirling Technology Company (STC) of Richland, WA. Each design features a free-piston Stirling engine, a liquid metal heat pipe receiver, and a means to provide about 25 kW of electric power to a utility grid while meeting DOE's long term performance and cost goals. An independent assessment showed that both designs are manufacturable and have the potential to easily meet DOE's long term cost goals.

Author

**N89-26887\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

#### PHOTOVOLTAIC MODULE ON-ORBIT ASSEMBLY FOR SPACE STATION FREEDOM

THOMAS SOURS, R. LOVELY, and D. CLARK 1989 10 p

Presented at the 24th Intersociety Energy Conversion Engineering Conference, Washington, DC, 6-11 Aug. 1989; cosponsored by the IEEE, AIAA, ANS, ASME, SAE, ACS, and AIChE

(NASA-TM-102297; E-4973; NAS 1.15:102297) Avail: NTIS HC A02/MF A01 CSCL 22/2

One of the elements of the Space Station Freedom power system is the Photovoltaic (PV) module. These modules will be assembled on-orbit during the assembly phase of the program. These modules will be assembled either from the shuttle orbiter or from the Mobile Servicing Center (MSC). The different types of assembly operations that will be used to assemble PV Modules are described.

Author

**N89-26888\*** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

#### ALTERNATE SPACE STATION FREEDOM CONFIGURATION CONSIDERATIONS TO ACCOMMODATE SOLAR DYNAMIC POWER

L. J. DERYDER, J. N. CRUZ, M. L. HECK, B. P. ROBERTSON, and P. A. TROUTMAN 28 May 1989 35 p

(NASA-TM-101603; NAS 1.15:101603) Avail: NTIS HC A03/MF A01 CSCL 22/2

The results of a technical audit of the Space Station Freedom Program conducted by the Program Director was announced in early 1989 and included a proposal to use solar dynamic power generation systems to provide primary electrical energy for orbital flight operations rather than photovoltaic solar array systems. To generate the current program baseline power of 75 kW, two or more solar concentrators approximately 50 feet in diameter would be required to replace four pairs of solar arrays whose rectangular blanket size is approximately 200 feet by 30 feet. The photovoltaic power system concept uses solar arrays to generate electricity that is stored in nickel-hydrogen batteries. The proposed concept uses the solar concentrator dishes to reflect and focus the Sun's energy to heat helium-xenon gas to drive electricity generating turbines. The purpose here is to consider the station configuration issues for incorporation of solar dynamic power system components. Key flight dynamic configuration geometry issues are addressed and an assembly sequence scenario is developed.

Author

**N89-26903\*** Cummings (Robert L.), Litchfield, OH. PERFORMANCE ESTIMATES FOR THE SPACE STATION POWER SYSTEM BRAYTON CYCLE COMPRESSOR AND TURBINE Final Report

ROBERT L. CUMMINGS Aug. 1989 35 p

(Contract NASA ORDER C-22187-M)

(NASA-CR-182263; E-4657; NAS 1.26:182263) Avail: NTIS HC A03/MF A01 CSCL 21/8

The methods which have been used by the NASA Lewis Research Center for predicting Brayton Cycle compressor and



turbine performance for different gases and flow rates are described. These methods were developed by NASA Lewis during the early days of Brayton cycle component development and they can now be applied to the task of predicting the performance of the Closed Brayton Cycle (CBC) Space Station Freedom power system. Computer programs are given for performing these calculations and data from previous NASA Lewis Brayton Compressor and Turbine tests is used to make accurate estimates of the compressor and turbine performance for the CBC power system. Results of these calculations are also given. In general, calculations confirm that the CBC Brayton Cycle contractor has made realistic compressor and turbine performance estimates.

Author

**N89-27256\*** University of South Florida, Tampa.  
**THERMAL EVALUATION OF ADVANCED SOLAR DYNAMIC  
 HEAT RECEIVER PERFORMANCE** Final Report, Jan - Dec.  
 1988

ROGER A. CRANE Mar. 1989 131 p

(Contract NAG3-851)

(NASA-CR-185117; NAS 1.26:185117) Avail: NTIS HC A07/MF  
 A01 CSCL 10/1

The thermal performance of a variety of concepts for thermal energy storage as applied to solar dynamic applications is discussed. It is recognized that designs providing large thermal gradients or large temperature swings during orbit are susceptible to early mechanical failure. Concepts incorporating heat pipe technology may encounter operational limitations over sufficiently large ranges. By reviewing the thermal performance of basic designs, the relative merits of the basic concepts are compared. In addition the effect of thermal enhancement and metal utilization as applied to each design provides a partial characterization of the performance improvements to be achieved by developing these technologies.

Author

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#### DEVELOPMENT AND REFINEMENT OF TEST BED SIMULATIONS

NARAYAN V. DRAVID, DEAN R. MILLER, ALEX G. PATTERSON,  
 and FRANK J. GOMBOS (Rockwell International Corp., Canoga  
 Park, CA.) Aug. 1989 8 p Presented at the 24th Intersociety  
 Energy Conversion Engineering Conference, Washington, DC, 6-11  
 Aug. 1989; sponsored in part by IEEE, AIAA, ANS, ASME, SAE,  
 ACS, and AICHE

(NASA-TM-102335; E-5043; NAS 1.15:102335) Avail: NTIS HC  
 A02/MF A01 CSCL 14/2

Lewis Research Center of NASA, with support from Rocketdyne, was engaged in non-real time computer simulation effort for the Space Station Freedom Electric Power System (EPS) EASY5, a simulation package, is used as the primary tool for this activity. Early in the design of the EPS, two test beds were set up at Lewis. The Integrated Test Bed (ITB), that combines and upgrades these test beds, is in the planning stage. The test beds are designed to functionally represent many of the components of the EPS and their interconnections. The simulation effort is primarily directed towards these test beds. Model verification is performed using test bed data.

Author

**N89-27704\*** National Aeronautics and Space Administration.  
 Lewis Research Center, Cleveland, OH.

#### TOWARD AN ELECTRICAL POWER UTILITY FOR SPACE EXPLORATION

ROBERT W. BERCAW 1989 6 p Prepared for presentation  
 at the European Space Power Conference, Madrid, Spain, 2-6  
 Oct. 1989; sponsored in part by ESA

(NASA-TM-102347; E-5055; NAS 1.15:102347) Avail: NTIS HC  
 A02/MF A01 CSCL 10/2

Plans for space exploration depend on today's technology programs addressing the novel requirements of space-based enterprise. The requirements for electrical power will be formidable: megawatts in magnitude, reliability for multi-year missions and the flexibility to adapt to needs unanticipated at design time. The

reasons for considering the power management and distribution in the various systems from a total mission perspective, rather than simply extrapolating current spacecraft design practice, are discussed. A utility approach to electric power being developed at the Lewis Research Center is described. It integrates requirements from a broad selection of current development programs with studies in which both space and terrestrial technologies are conceptually applied to exploration mission scenarios.

Author

**N89-27705\*** National Aeronautics and Space Administration.  
 Lewis Research Center, Cleveland, OH.

#### NASA ADVANCED SPACE PHOTOVOLTAIC TECHNOLOGY-STATUS, POTENTIAL AND FUTURE MISSION APPLICATIONS

DENNIS J. FLOOD, MICHAEL PISZCZOR, JR., PAUL M. STELLA,  
 and GARY L. BENNETT (National Aeronautics and Space  
 Administration, Washington, DC.) 1989 8 p Prepared for  
 presentation at the European Space Power Conference, Madrid,  
 Spain, 2-6 Oct. 1989; sponsored in part by ESA

(NASA-TM-102093; E-4856; NAS 1.15:102093) Avail: NTIS HC  
 A02/MF A01 CSCL 10/2

The NASA program in space photovoltaic research and development encompasses a wide range of emerging options for future space power systems, and includes both cell and array technology development. The long range goals are to develop technology capable of achieving 300 W/kg for planar arrays, and 300 W/sq m for concentrator arrays. InP and GaAs planar and concentrator cell technologies are under investigation for their potential high efficiency and good radiation resistance. The Advanced Photovoltaic Solar Array (APSA) program is a near term effort aimed at demonstrating 130 W/kg beginning of life specific power using thin (62 micrometer) silicon cells. It is intended to be technology transparent to future high efficiency cells and provides the baseline for development of the 300 W/kg array.

Author

**N89-27717\*** Jet Propulsion Lab., California Inst. of Tech.,  
 Pasadena.

#### SPACECRAFT AND MISSION DESIGN FOR THE SP-100 FLIGHT EXPERIMENT

WILLIAM D. DEININGER and ROBERT J. VONORA (Schafer, W.  
 J. Associates, Inc., Arlington, VA.) In DGLR, DGLR/AIAA/JSASS  
 20th International Electric Propulsion Conference: Proceedings p  
 86-98 1988 Sponsored in part by the Strategic Defense  
 Initiative Organization, Washington, DC

Avail: NTIS HC A99/MF E03 CSCL 10/2

The design and performance of a spacecraft employing arcjet nuclear electric propulsion, suitable for use in the SP-100 Space Reactor Power System (SRPS) Flight Experiment, are outlined. The vehicle design is based on a 93 kW(e) ammonia arcjet system operating at an experimentally measured specific impulse of 1031 s and an efficiency of 42.3 percent. The arcjet/gimbal assemblies, power conditioning subsystem, propellant feed system, propulsion system thermal control, spacecraft diagnostic instrumentation, and the telemetry requirements are described. A 100 kW(e) SRPS is assumed. The spacecraft mass is baselined at 5675 kg excluding the propellant and propellant feed system. Four mission scenarios are described which are capable of demonstrating the full capability of the SRPS. The missions considered include spacecraft deployment to possible surveillance platform orbits, a spacecraft storage mission, and an orbit raising round trip corresponding to possible orbit transfer vehicle (OTV) missions.

ESA

**N89-27719\*** Tokyo Univ., Sagami-hara (Japan). Inst. of Space  
 and Astronautical Science.

#### INTERACTION OF HIGH VOLTAGE SOLAR ARRAY WITH IONOSPHERIC PLASMA

H. KUNINAKA, S. SATORI, Y. NOZAKI, and KYOICHI KURIKI In  
 DGLR, DGLR/AIAA/JSASS 20th International Electric Propulsion  
 Conference: Proceedings p 105-114 1988

Avail: NTIS HC A99/MF E03

Interference phenomena on a high voltage solar array (HVSA) by the ionospheric plasma were studied. The influence of ion drag

## 07 POWER

on spacecraft motion, and surface degradation by sputtering are pointed out. ESA

### **N89-27721# Sovonics Solar Systems, Troy, MI. DEPLOYABLE AEROSPACE PHOTOVOLTAIC ARRAY BASED ON AMORPHOUS SILICON ALLOYS**

J. J. HANAK, LEE WALTER, DAVID DOBIAS, and HARVEY FLAISHER In DGLR, DGLR/AIAA/JSASS 20th International Electric Propulsion Conference: Proceedings p 121-124 1988  
Avail: NTIS HC A99/MF E03

An ultralight, stowable, and deployable photovoltaic (PV) array is described for aerospace applications such as in lightweight space vehicles and high altitude balloons. The array consists of thin-film, tandem-junction, amorphous silicon alloy solar cells deposited onto a thin metallic foil. The array design utilizes 20 giant-sized cells, 1566 sq cm in area, connected in series to provide power of 207 W at AMO illumination. The weight of the array is only 800 g, which results in a power density of 258 W/kg, one order of magnitude greater than existing space arrays. Each of the cells is fully protected with bypass diodes to prevent damage upon partial shading or cell mismatch. A lightweight mechanism for stowing, deployment and support of the PV array was designed and a prototype constructed. The overall power density for the array and this mechanism is 145 W/kg. ESA

### **N89-28287# Politecnico di Torino (Italy). Dept. di Energetica.**

#### **INTERMEDIATE HEAT EXCHANGER FOR A NUCLEAR-POWERED SPACE POWER SYSTEM**

G. DELTIN, M. MALANDRONE, N. NERVEGNA, N. VALLE, P. G. AVANZINI, and A. TORRESI (Ansaldo S.p.A., Genoa, Italy) In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 529-535 Dec. 1988  
Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

The analysis and design of an Intermediate Heat Exchanger (IHX) operated under constraints of power, temperature, pressure, redundancy and size, and suitable for integration in a 200 kW space nuclear generator system is presented. Exchanged thermal power is in the range of 1050 kW being liquid lithium the IHX shell side coolant fluid. Tube side fluid is an He-Xe mixture, rated at the molecular mass of Ar (39.9) to compromise turbomachinery performances and heat exchange processes. Specifications on normal operating temperatures are: in the selected counterflow arrangement lithium enters the shell side at 1197 C, while the gas mixture enters the IHX at 735 C. Since the two existing lithium loops are low pressure operated and being low velocity, for which a typical transition flow regime must be accounted. Secondary loops, four at normal operating conditions, are wholly independent and arranged in parallel with an operating pressure of 10 bar and a compression ratio of 2.2. Thus, the flow is fully turbulent. The selected containment material for the lithium side is the (MoRe) alloy, while a (TaW) alloy was designated for the gas side. Straight tubes partitioned in four bundles individually feed respective turbomachines, this solution providing some degree of redundancy in case of failure of one rotating unit. ESA

### **N89-29484# National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.**

#### **A PROGRAM FOR ADVANCING THE TECHNOLOGY OF SPACE CONCENTRATORS**

GERALD J. NAJOKAS (Sverdrup Technology, Inc., Cleveland, OH) and JOSEPH M. SAVINO 1989 8 p Presented at the 24th Intersociety Energy Conversion Engineering Conference, Washington, DC, 6-11 Aug. 1989; cosponsored by IEEE, AIAA, ANS, ASME, SAE, ACS, and AIChE  
(NASA-TM-102139; E-4900; NAS 1.15:102139) Avail: NTIS HC A02/MF A01 CISC 10/1

In 1985, the NASA Lewis Research Center formed a project, the Advanced Solar Dynamics Power Systems Project, for the purpose of advancing the technology of Solar Dynamic Power Systems for space applications beyond 2000. Since then, technology development activities have been initiated for the major

components and subsystems such as the concentrator, heat receiver and engine, and radiator. Described here is a program for developing long lived (10 years or more), lighter weight, and more reflective space solar concentrators than is presently possible. The program is progressing along two parallel paths: one is concentrator concept development and the other is the resolution of those critical technology issues that will lead to durable, highly specular, and lightweight reflector elements. Outlined are the specific objectives, long term goals, approach, planned accomplishments for the future, and the present status of the various program elements. Author

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## ELECTRONICS

Includes descriptions of analytical techniques, analyses, systems, and requirements for internal and external communications, electronics, sensors for position and systems monitoring and antennas.

### **A89-32885\* National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.**

#### **MECHANICAL PROPERTIES CHARACTERIZATION OF COMPOSITE SANDWICH MATERIALS INTENDED FOR SPACE ANTENNA APPLICATIONS**

KENNETH J. BOWLES and RAYMOND D. VANNUCCI (NASA, Lewis Research Center, Cleveland, OH) In: Test methods and design allowables for fibrous composites. Volume 2. Philadelphia, PA, American Society for Testing and Materials, 1989, p. 31-44. Previously announced in STAR as N88-10121. refs  
Copyright

The composite materials proposed for use in the Advanced Communications Technology Satellite (ACTS) program contains a new, high modulus graphite fiber as the reinforcement. A study was conducted to measure certain mechanical properties of the new fiber-reinforced material as well as of a composite-faced aluminum honeycomb sandwich structure. Properties were measured at -157, 22, and 121 C. Complete characterization of this material was not intended. Longitudinal tensile, picture-frame shear, short-beam shear, and flexural tests were performed on specimens of the composite face-sheet materials. Unidirectional, cross-piled, and quasi-isotropic fiber composite ply layup designs were fabricated and tested. These designs had been studied by using NASA's Integrated Composite Analyzer (ICAN) computer program. Flexural tests were conducted on (+/- 60/0 deg) sub s composite-faced sandwich structure material. Resistance strain gages were used to measure strains in the tensile, picture-frame, and sandwich flexural tests. The sandwich flexural strength was limited by the core strength at 157 and 22 c. The adhesive bond strength was the limiting factor at 121 C. Adhesive mechanical properties are reflected in sandwich structure flexural properties when the span-to-depth ratio is great enough to allow a significant shear effect on the load-deflection behavior of the sandwich beam. Most measured properties agreed satisfactorily with the properties predicted by ICAN. Author

### **A89-35347#**

#### **HIGH-PRECISION OPTOELECTRONIC MEASUREMENT SYSTEM FOR THREE-DIMENSIONAL DETERMINATION OF RELATIVE ATTITUDE AND POSITION (HOCHPRAEZISES OPTOELEKTRONISCHES MESSSYSTEM ZUR DREIDIMENSIONALEN BESTIMMUNG VON RELATIVER LAGE UND POSITION)**

R. LUTZ (Messerschmitt-Boelkow-Blom GmbH, Munich, Federal Republic of Germany) (URSI and Informationstechnische Gesellschaft, Gemeinsame Tagung, Kleinheubach, Federal Republic of Germany, Oct. 3-7, 1988) Kleinheubacher Berichte (ISSN 0343-5725), vol. 32, 1988, p. 343-350. In German.

An optoelectronic sensor system for highly precise

two-dimensional measurement of angles has been developed. The optical concept of the system is reviewed, and the position measuring procedure using lateral effect photodiodes is described. Theoretical limits for the noise-equivalent position resolution are outlined and discussed, and the signal processing in the measurement system is summarized. The technical realization of the system and some measurement results are addressed. C.D.

**A89-36821\*** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**INTEGRATED STRUCTURAL ELECTROMAGNETIC SHAPE CONTROL OF LARGE SPACE ANTENNA REFLECTORS**  
S. L. PADULA, H. M. ADELMAN, M. C. BAILEY (NASA, Langley Research Center, Hampton, VA), and R. T. HAFTKA (Virginia Polytechnic Institute and State University, Blacksburg) (Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987, Technical Papers, Part 1, p. 508-517) AIAA Journal (ISSN 0001-1452), vol. 27, June 1989, p. 814-819. Previously cited in issue 14, p. 2115, Accession no. A87-33611. refs

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**A89-37218\*** Ohio State Univ., Columbus.

**A SURFACE DISTORTION ANALYSIS APPLIED TO THE HOOP/COLUMN DEPLOYABLE MESH REFLECTOR ANTENNA**  
TEH-HONG LEE, ROGER C. RUDDUCK (Ohio State University, Columbus), and MARION C. BAILEY (NASA, Langley Research Center, Hampton, VA) IEEE Transactions on Antennas and Propagation (ISSN 0018-922X), vol. 37, April 1989, p. 452-458. Research supported by the Ohio State University. refs (Contract NAS1-17450)

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A practical approach is demonstrated for the deterministic analysis of surface distortions in reflector antennas, based on a first-order approximation to the aperture field phase. Measured pattern results from a 15-m-diameter hoop/column deployable mesh reflector antenna are used to demonstrate the accuracy which can be obtained with this surface distortion analysis. The only practical limitation of the first-order approximation is determined by the slope derivations of the distorted surface from the best-fit paraboloid. I.E.

**A89-37648**

**THE VITAL CONNECTION**

IAN PARKER Space (ISSN 0267-954X), vol. 5, Mar.-Apr. 1989, p. 41, 42.

Copyright

The technical aspects of spacecraft wiring are reviewed. Space cable applications, insulations for spacecraft wires, and the outgassing process are discussed. Several products are considered, including polytetrafluoroethylene insulation, solar array system cables, power supply cables, and hookup system cables.

R.B.

**A89-43718\*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

**ADVANCED TECHNOLOGY FOR SPACE COMMUNICATIONS, TRACKING, AND ROBOTIC SENSORS**  
KUMAR KRISHNEN (NASA, Johnson Space Center, Houston, TX) IN: Space - A new community of opportunity; Proceedings of the Thirty-fourth Annual AAS International Conference, Houston, TX, Nov. 3-5, 1987. San Diego, CA, Univelt, Inc., 1989, p. 273-290. refs

(AAS PAPER 87-652) Copyright

Technological advancements in tracking, communications, and robotic vision sensors are reviewed. The development of communications systems for multiple access, broadband, high data rate, and efficient operation is discussed. Consideration is given to the Tracking and Data Relay Satellite systems, GPS, and communications and tracking systems for the Space Shuttle and the Space Station. The use of television, laser, and microwave sensors for robotics and technology for autonomous rendezvous and docking operations are examined. R.B.

**A89-43718**

**SPACE STATION COMMUNICATIONS**

ALBERT W. WEINRICH (RCA, Government Communication Systems Div., Camden, NJ) IN: Space - A new community of opportunity; Proceedings of the Thirty-fourth Annual AAS International Conference, Houston, TX, Nov. 3-5, 1987. San Diego, CA, Univelt, Inc., 1989, p. 295-299.

(AAS PAPER 87-653) Copyright

Plans for the Space Station communications system are reviewed. The components of the communications system are described, including the Communications and Tracking System, the Tracking and Data Relay Satellite System, GPS, the data interface facility, the data handling facility. Video communications and space-to-ground and space-to-space communications are discussed. R.B.

**A89-45530**

**APPLICATIONS AND REQUIREMENTS OF LASER DIODES FOR FREE-SPACE LASER COMMUNICATIONS**

DAVID L. BEGLEY (Bell Corp., Bell Aerospace Systems Group, Boulder, CO) IN: Laser diode technology and applications; Proceedings of the Meeting, Los Angeles, CA, Jan. 18-20, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers (SPIE Proceedings, Volume 1043), 1989, p. 274-283. refs

Copyright

An overview of spaceborne laser communication systems is presented, and key laser diode parameters which affect their applications are discussed. Particular consideration is given to the principles of a laser communications terminal and its basic components and subsystems. Applications and requirements of laser diodes for free-space laser communications in both the commercial and defense areas are examined. A functional block diagram and a design diagram for generic laser communications terminal are included. I.S.

**A89-45814**

**XLA - THE X-RAY LARGE ARRAY**

KENT S. WOOD (U.S. Navy, Naval Research Laboratory, Washington, DC) and PETER F. MICHELSON (Stanford University, CA) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 1071-1082. Research supported by the U.S. Navy. refs

Copyright

The concept of a large (100-sq m) array of X-ray detectors (XLA), which will be constructed at the NASA Space Station and used there for astrophysical observations, is examined, together with the aspects of its construction and operations. Consideration is also given to the natural phenomena that can be observed by X-ray spectroscopy and to the all-sky X-ray sources. It is emphasized that XLA data can be used to map the most extended structures known to X-ray astronomy, such as the tenuous plasma in the halos of clusters of galaxies. Design diagrams of the XLA assembly and its mounting configurations are included. I.S.

**A89-46213**

**ACCEPTANCE TEST EFFECTIVENESS INCLUDING 'HIGH LEVEL ACOUSTIC TESTING'**

D. A. SMITH (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: Institute of Environmental Sciences, Annual Technical Meeting, 34th, King of Prussia, PA, May 3-5, 1988, Proceedings. Mount Prospect, IL, Institute of Environmental Sciences, 1988, p. 120-130. refs

Copyright

Results are presented from a study to identify the environmental stress screening (ESS) effectiveness of black box and spacecraft system level acceptance testing. Acceptance test data from June 1978 to September 1985 are analyzed to determine the effectiveness of thermal vacuum cycling, temperature cycling burn-in, and random vibration ESS at the black box test level and high level acoustic and thermal vacuum cycle ESS testing at the spacecraft system test level. The effect of proposed printed wiring



assembly (Card) level testing on existing black box level programs is considered. It is found that 67.5 percent of the failures were in the preenvironment ambient functional testing with 23.4 percent during the thermal-vacuum test. R.B.

**AB9-46533\*** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

**BEAMED LASER POWER FOR ADVANCED SPACE MISSIONS**  
E. J. CONWAY and R. J. DE YOUNG (NASA, Langley Research Center, Hampton, VA) (IAF, International Conference on Space Power, Cleveland, OH, June 5-7, 1989) Space Power (ISSN 0951-5089), vol. 8, no. 3, 1989, p. 357-363. refs (IAF PAPER ICOSP89-10-4) Copyright

Advanced civil space missions may benefit substantially from beamed laser power. Recent advances in solar-pumped lasers and electrically driven diode lasers are discussed. Two laser-beamed power applications, for an advanced space station and in support of a high power lunar base, are summarized.

Author

**AB9-46534\*** Texas A&M Univ., College Station.

**FEASIBILITY STUDY OF 35 GHz MICROWAVE POWER TRANSMISSION IN SPACE**

K. CHANG, J. C. MCCLEARY, and M. A. POLLOCK (Texas A & M University, College Station) (IAF, International Conference on Space Power, Cleveland, OH, June 5-7, 1989) Space Power (ISSN 0951-5089), vol. 8, no. 3, 1989, p. 365-370. Research supported by NASA. refs

(IAF PAPER ICOSP89-10-5) Copyright

This paper is a study of the feasibility of a 35-GHz microwave power transmission system in space. It was found that a dc to dc transmission efficiency better than 50 percent can be achieved over a distance of 50 km by using a transmitting antenna of 20 m in diameter and a receiving antenna of 40 m in diameter. Technology requirements at 35 GHz have been assessed and several stages of development have been proposed. Author

**AB9-47589**

**THE MBB UNFURLABLE MESH ANTENNA (UMA) - DESIGN AND DEVELOPMENT**

H. KELLERMEIER and H. VORBRUGG IN: Military microwaves '88; Proceedings of the Sixth Conference, London, England, July 5-7, 1988. Turbridge Wells, England, Microwave Exhibitions and Publishers, Ltd., 1988, p. 82-90. refs

Copyright

The unfurlable mesh antenna (UMA) technology has been developed since 1983. It covers various communications satellite applications in the range between 850 MHz up to 12 GHz with reflector diameters from 3.2 to 12 meters which meet surface errors between 0.1 and 1.4 mm. This versatility could best be met by a new radial rib concept where foldable main ribs and intermediate ribs tension a gold plated molybdenum mesh to the required surface contour. The accuracy is varied by applying different number of ribs and mesh-fastening prints. Author

**AB9-51434**

**MICROPROCESSORS IN SPACE INSTRUMENTATION**

M. P. GOUGH (Sussex University, Brighton, England) and L. J. C. WOOLLISCROFT (Sheffield University, England) Space Technology - Industrial and Commercial Applications (ISSN 0892-8270), vol. 9, no. 3, 1989, p. 305-313. Research supported by SERC and University Grants Committee. refs

Copyright

The current level of integration of microprocessors with space instrumentation is reviewed. Their inclusion provides the benefits of improved measurement resolution, improved reliability, a more efficient use of limited spacecraft resources, and further provides control for the latest complex instruments. In the past microprocessors were limited to just controlling instruments and simple buffering of the data produced for the spacecraft telemetry system. Already microprocessors are being relied on to perform mission critical calculations while future uses involve increased on-board intelligence and even on-board expert systems. Author

**AB9-22548#** Alcatel Espace, Toulouse (France).

**STUDY OF A DRS EXPERIMENTAL PAYLOAD FOR SINGLE AND MULTIPLE ACCESS AT S BAND: EXECUTIVE SUMMARY**

J. NERON Paris, France ESA 10 May 1988 46 p (Contract ESTEC-7140/87/NL/DG) (PSDB8/00017; ESA-CR(P)-2751; ETN-89-94472) Copyright Avail: NTIS HC A03/MF A01

Antenna concepts for ESA's DRS satellite were studied, and the possibility of reusing the reflector for an experimental land mobile telecommunications mission was investigated. Concerning the large reflector, there is no significant advantage for any technology and the choice depends on the antenna and even spacecraft configuration. When a central attachment of the reflector is requested, the MBB UMA technology is the most suitable. For offset configurations, the light weight of the ISRS is interesting but, for unsymmetrical configurations, it induces a solar torque which leads to tens of kilograms of propellant consumption to compensate it. Thus, for unsymmetrical configurations, the Aerospatiale technology is more adequate. The antenna concept depends on the final mission priorities. To provide one S band single access beam, the center fed fully steerable antenna concept offers the best performances. But as this mission will be requested only for a small percentage of the time, the interest of this configuration for a flight on SAT-2 is limited. For implementation of several missions such as S band plus land mobile plus, as an option, LOCSTAR, offset fed concepts are more suitable. ESA

**AB9-24384#** European Space Agency, European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).

**THE CONCEPT OF TELESCEANCE**

P. BUIA In: International Symposium on Europe in Space: The Manned Space System p 441-445 Oct. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The concept of telesceance is defined and the ESA telesceance program is introduced. Telesceance is a mode of payload operation whereby ground based users can interactively control their payloads on Columbus elements. The telesceance program test beds and technology support preparation; system design and simulation; and operational requirements analysis are summarized. ESA

**AB9-24385#** LABEN Space Instrumentation and Systems, Milan (Italy). Advanced Research and Development Dept.

**TELESCEANCE AND PAYLOAD CONTROL SUPPORT TECHNOLOGIES**

P. DONZELLI and E. MACAVERO In: ESA, International Symposium on Europe in Space: The Manned Space System p 447-453 Oct. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

Technological options and their utilization scenarios for telesceance implementation in manned space stations are outlined. On board and ground based data acquisition systems (SMD and MIMO architecture, digital signal processing); and real time knowledge based systems to support principal investigators and payload specialists are discussed. ESA

**AB9-24386#** MATRA Espace, Toulouse (France).

**TELESCEANCE: A PROMISING OPERATIONS CENTER**

PH. LEBOUAR and C. LOEILLET In: ESA, International Symposium on Europe in Space: The Manned Space System p 455-463 Oct. 1988

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The telesceance operations environment and requirements are outlined, and a telesceance concept is described. The concept includes a communication network and an onboard data management system. Consequences of the telesceance concept for the Columbus user support and operations centers and payload operations control center are assessed. Validation of the telesceance concept is discussed. ESA

**N89-25363\*** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

**ANTENNA SURFACE CONTOUR CONTROL SYSTEM Patent**  
ELVIN L. AHL, inventor (to NASA) and JAMES B. MILLER, inventor (to NASA) 7 Mar. 1989 14 p  
(NASA-CASE-LAR-13798-1; US-PATENT-4,811,033;  
US-PATENT-APPL-SN-118995; US-PATENT-CLASS-343-880;  
US-PATENT-CLASS-343-915; US-PATENT-CLASS-343-DIG.2)  
Avail: U.S. Patent and Trademark Office

The invention is a system for automatically controlling the surface contour of a deployable and restorable antenna having a mesh reflector surface supported by a circular, folding hoop affixed to a central, telescoping column. The antenna, when deployed, forms a quad-aperture reflector with each quadrant of the mesh surface shaped to provide an offset parabolic radio frequency (RF) reflector. The hoop is supported and positioned by quartz support cords attached to the top of a column and by lower graphite hoop control cords that extend between the hoop and base of the column. The antenna, an RF reflective surface, is a gold plated molybdenum wire mesh supported on a graphite cord buss structure that includes the hoop control cords and a plurality of surface control cords attached at selected points on the surface and to the base of the column. The contour of the three-dimensional surface of the antenna is controlled by selectively adjusting the lengths of the surface control cords and the graphite hoop control cords by means of novel actuator assemblies that automatically sense and change the lengths of the lower hoop control cords and surface control cords.

Official Gazette of the U.S. Patent and Trademark Office

**N89-26503\*** Honeywell Systems and Research Center, Minneapolis, MN.

#### THE ARCHITECTURE OF A VIDEO IMAGE PROCESSOR FOR THE SPACE STATION

S. YALAMANCHILI, D. LEE, K. FRITZE, T. CARPENTER, K. HOYME, and N. MURRAY (National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.) in Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 2 p 85-93 1 Jul. 1987

Avail: NTIS HC A18/MF A03 CSCL 09/2

The architecture of a video image processor for space station applications is described. The architecture was derived from a study of the requirements of algorithms that are necessary to produce the desired functionality of many of these applications. Architectural options were selected based on a simulation of the execution of these algorithms on various architectural organizations. A great deal of emphasis was placed on the ability of the system to evolve and grow over the lifetime of the space station. The result is a hierarchical parallel architecture that is characterized by high level language programmability, modularity, extensibility and can meet the required performance goals. Author

**N89-28261\*** Dornier System G.m.b.H., Friedrichshafen (Germany, F.R.).

#### THERMAL ASPECTS OF THE ERS-1 SAR ANTENNA DEPLOYMENT

G. JANDER, F. ZILLY, and R. BISANZ in ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 345-350 Dec. 1988

Copyright Avail: NTIS HC A89/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

Transferring the deployable elements of the ERS-1 SAR antenna from stowed into deployed configuration is considered as the most critical activity within the LEOP (Launch and Early Orbit Phase) operational sequence. The deployment of the different elements of the ERS-1 has to be studied carefully and the operational sequencing of events has to be embedded into an overall LEOP scenario considering various constraints. Besides the nominal operational conditions the deployment was studied for various scenarios, including failure cases (contingency scenarios). Relevant scenarios including partly deployed antenna

panels and their analytical treatment, e.g., standard thermal mathematical models, raytracing techniques for sun trapping, and engineering assessment are described. ESA

**N89-28550\*** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

#### NEAR-FIELD TESTING OF THE 15-METER HOOP-COLUMN ANTENNA

LYLE C. SCHROEDER, RICHARD R. ADAMS, M. C. BAILEY, W. KEITH BELVIN, DAVID H. BUTLER, and THOMAS G. CAMPBELL Aug. 1989 121 p  
(NASA-TM-4073; L-16410; NAS 1.15:4073) Avail: NTIS HC A07/MF A01 CSCL 20/14

A 15-m-diameter antenna was tested to verify that dimensional tolerances for acceptable performance could be achieved and to verify structural, electromagnetic, and mechanical performance predictions. This antenna utilized the hoop column structure, a gold plated molybdenum mesh reflector, and 96 control cables to adjust the reflector conformance with a paraboloid. The dimensional conformance of the antenna structure and surface was measured with metric camera and theodolites. Near field pattern data were used to assess the electromagnetic performance at five frequencies from 2.225 to 11.8 GHz. The reflector surface was adjusted to greatly improve electromagnetic performance with a finite element model and the surface measurements. Measurement results show that antenna surface figure and adjustments and electromagnetic patterns agree well with predictions. Author

## 09

### PROPULSION/FLUID MANAGEMENT

Includes descriptions, analyses, and subsystem requirements for propellant/fluid management and propulsion systems for attitude control and orbit maintenance and transfer for the station and supporting elements such as the OMV and OTV.

**A89-34940**

#### A THEORETICAL STUDY OF INDUCTION

##### ELECTROHYDRODYNAMIC PUMPING IN OUTER SPACE

J. SEYED-YAGOOBI (Texas A & M University, College Station) IN: Collected papers in heat transfer 1988; Proceedings of the ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 69-76.

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A numerical investigation is presented of induction electrohydrodynamic (EHD) pumping in the absence of gravity. Both attraction and repulsion modes are considered. Results indicate that operation of the induction EHD pump in space is similar to that when gravity is present. In addition, the pump operates similarly in the attraction and repulsion modes, except that the values of the critical frequency and the electrical conductivity level are, respectively, lower and higher in the repulsion mode. Higher velocities are obtained with steeper entrance temperature profiles, higher fluid bulk temperature, and heat fluxes at the pipe wall. Operation at higher voltages, lower wavelengths, and critical frequency and electrical conductivity levels also result in higher velocities. S.A.V.

**A89-38148**

#### CRYOGENIC SYSTEM OF HE II COOLED INFRARED TELESCOPE ONBOARD SFU

MASAHIDE MURAKAMI (Tsukuba, University, Japan), GENSHIRO FUJII (NEC Corp., Yokohama, Japan), and MAKOTO KYOYA (Sumitomo Heavy Industries, Ltd., Ehime, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings, Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 905-910. refs

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## 09 PROPULSION/FLUID MANAGEMENT

An infrared telescope (IRTS) is planned to be launched in 1993, which will be accommodated to the Space Flyer Unit (SFU). It is cooled down to 1.8 K by 100 l of stored superfluid helium. The cooled-mission lifetime is requested to be longer than several weeks. Minimization of heat leak to the lowest temperature level is one of the primary design points for the maximum lifetime. The liquid oxygen management in the zero-g situation is another key item. The ground operation at the launching site should also be well planned, especially in liquid helium treatment. Author

### A89-28796

#### GEOMAGNETIC ORIGIN FOR TRANSIENT PARTICLE EVENTS FROM NUCLEAR REACTOR-POWERED SATELLITES

G. H. SHARE, J. D. KURFESS, K. W. MARLOW (U.S. Navy, Naval Research Laboratory, Washington, DC), and D. C. MESSINA (Sachs/Freeman Associates, Inc., Landover, MD) Science (ISSN 0036-8075), vol. 244, April 28, 1989, p. 444-448. refs

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Transient events observed since 1960 by the Gamma-Ray Spectrometer experiment on the Solar Maximum Mission satellite (SMM) have been identified with radiation emitted from 18 different Soviet nuclear reactor-powered satellites. Most of these satellites are similar to Cosmos 954 and 1402 which reentered the atmosphere. Gamma radiation from these satellites was detected when they passed within about 400 to 500 kilometers of SMM. Positron annihilation line radiation (511 kiloelectron volts) and charged-particle events were detected when SMM encountered clouds of positrons and electrons emitted by these satellites and stored up to tens of minutes in the geomagnetic field. The rate of these events varied from about 1 in 5 days to over 30 per day and was strongly dependent on the operating altitudes of the Cosmos satellites and density of the upper atmosphere. Author

### A89-28797

#### DISTRIBUTION AND DETECTION OF POSITRONS FROM AN ORBITING NUCLEAR REACTOR

E. W. HONES and P. R. HIGBIE (Los Alamos National Laboratory, NM) Science (ISSN 0036-8075), vol. 244, April 28, 1989, p. 448-451. Research supported by DOE. refs

Copyright

The Solar Maximum Mission (SMM) Gamma-Ray Spectrometer has on many occasions detected nuclear radiation produced by nuclear reactors carried on Soviet satellites. A unique feature of the observations is the measurement of bursts of 511-kiloelectron volt gamma rays that are thought to signal SMM encounters with positrons emanating from the Soviet satellites. A model of positron generation by an orbiting reactor has been developed that describes the resulting time-dependent distribution of positrons temporarily trapped in the geomagnetic field and estimates the response of the SMM spectrometer to passage through such distributions. The model successfully predicts onset times, durations, and intensities of the 511-kiloelectron volt gamma bursts, and thus confirms that these are due to positrons from the Soviet satellites. Author

### A89-29156\*# Alabama Univ., Huntsville.

#### BUBBLE BEHAVIORS IN A SLOWLY ROTATING HELIUM DEWAR IN A GRAVITY PROBE-B SPACECRAFT EXPERIMENT

R. J. HUNG, Y. D. TSAO (Alabama University, Huntsville), FRED W. LESLIE (NASA, Marshall Space Flight Center, Huntsville, AL), and B. B. HONG Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 26, May-June 1989, p. 167-172. refs (Contract NAG8-035)

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Potential problems for the Gravity Probe-B (GP-B) spacecraft design requirements and the operational considerations could arise because of the free surface configurations between liquid helium and helium vapor in the rotating dewar. This free surface is present in the partially filled liquid helium dewar. The liquid helium in the dewar is depleted as it is consumed as propellant for the spacecraft. In this study, the doughnut-shaped helium bubble equilibrium profiles in the rotating dewar have been numerically calculated. These calculations were performed under the conditions imposed

during the period of the GP-B experiment instrument calibration (gyro spinup period) and also during the normal operational stages of the GP-B spacecraft. Author

### A89-40849

#### NUCLEAR PROPULSION FOR ORBITAL TRANSFER

G. ALLEN BEALE and TIMOTHY J. LAWRENCE (USAF, Astronautics Laboratory, Edwards AFB, CA) Aerospace America (ISSN 0740-722X), vol. 27, June 1989, p. 27-29.

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The state of the art in nuclear propulsion for orbital transfer is discussed. Cryogenic propulsion, electric propulsion, solar-thermal propulsion and direct nuclear propulsion are examined in this context. New technologies with exceptional promise are addressed, emphasizing the particle test bed nuclear engine. C.D.

### A89-41303\*

#### SPACE CRYOGENICS WORKSHOP, UNIVERSITY OF WISCONSIN, MADISON, JUNE 22, 23, 1987

Workshop sponsored by NASA, Cryogenics (ISSN 0011-2275), vol. 28, Feb. 1988, 83 p. For individual items see A89-41304 to A89-41317.

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Papers are presented on liquid helium servicing from the Space Station, performance estimates in the Superfluid Helium On-Orbit Transfer Flight Experiment, an analytical study of He II flow characteristics in the SHOOT transfer line, a Dewar to Dewar model for superfluid helium transfer, and mechanical pumps for superfluid helium transfer in space. Attention is also given to the cavitation characteristics of a small centrifugal pump in He I and He II, turbulent flow pressure drop in various He II transfer system components, slip effects associated with Knudsen transport phenomena in porous media, and an integrated fountain effect pump device for fluid management at low gravity. Other papers are on liquid/vapor phase separation in He-4 using electric fields, an enclosed capillary device for low-gravity management of He II, cavitation in flowing superfluid helium, the long-term performance of the passive thermal control systems of the IRAS spacecraft, and a novel approach to supercritical helium flight crystal support structures. I.S.

### A89-41304\* Swales and Associates, Beltsville, MD.

#### LIQUID HELIUM SERVICING FROM THE SPACE STATION

S. R. BREON (Swales & Associates, Beltsville, MD) (NASA, Space Cryogenics Workshop, Madison, WI, June 22, 23, 1987) Cryogenics (ISSN 0011-2275), vol. 28, Feb. 1988, p. 68-76. refs (Contract NAS5-28554)

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The current concept of liquid helium resupply from the Space Station is discussed with regard to user and Space Station requirements, as well as requirements of the liquid helium servicing facility itself. A number of trade-offs which will affect both the hardware and the operation of the facility are presented. A total of 12 potential users have been identified. The users are divided into two groups: large volume users which are serviced every one to two years and small volume users which are serviced every few months. Both groups have a very strong impact on the definition of the liquid helium servicing facility. The facility components will be based on results of the Superfluid Helium On Orbit Transfer flight demonstration being conducted by NASA. Currently, the Space Station design includes a customer servicing bay which provides electrical power, thermal and contamination control, and connections for control and data handling systems. Restrictions on venting and vibrational disturbances on the Space Station may preclude servicing during quiescent periods when accelerations are minimal. Author

### A89-41305\* National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, MD.

#### SUPERFLUID HELIUM ON-ORBIT TRANSFER FLIGHT EXPERIMENT - PERFORMANCE ESTIMATES

M. J. DIPIRRO (NASA, Goddard Space Flight Center, Greenbelt, MD) (NASA, Space Cryogenics Workshop, Madison, WI, June



22, 23, 1987) Cryogenics (ISSN 0011-2275), vol. 28, Feb. 1988, p. 77-80. refs

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Several components on the Superfluid Helium On-Orbit Transfer Flight Experiment are analyzed with respect to expected performance. The interaction of the components is then used to calculate an expected transfer efficiency. Steady state conditions are assumed. Transfer efficiencies based on the thermomechanical pump range from 96 to 99 percent plus. Transfer line parasitics lead to lower efficiencies at low flow rates. Author

**A89-41306\*** National Aeronautics and Space Administration, Ames Research Center, Moffett Field, CA.

# **ANALYTICAL STUDY OF HE II FLOW CHARACTERISTICS IN THE SHOOT TRANSFER LINE**

J. H. LEE, Y. S. NG, and W. F. BROOKS (NASA, Ames Research Center, Moffett Field, CA) (NASA, Space Cryogenics Workshop, Madison, WI, June 22, 23, 1987) Cryogenics (ISSN 0011-2275), vol. 28, Feb. 1988, p. 81-85. refs

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Pressure and temperature profiles for He II flow in the transfer line for the Superfluid Helium On-Orbit Transfer (SHOOT) experiment are determined using a finite difference method to solve the one-dimensional two-fluid conservation equations. For practical purposes, forced flow of He II with Re greater than 10 to the 6th can be treated as a classical turbulent flow. For a maximum SHOOT transfer rate of 800 cu dm/h, the temperature rise between the pump outlet and the receiver tank is about 80 mK with a 7-W heat load imposed on the 4-m-long transfer line. A pump outlet pressure of 180 torr is required to sustain the 800 cu dm/h flow without causing vapor formation within the transfer line. Author

**A89-41307\*** Colorado Univ., Boulder.

# **DEWAR TO DEWAR MODEL FOR SUPERFLUID HELIUM TRANSFER**

H. A. SNYDER (Colorado, University; Bell Corp., Aerospace Systems Div., Boulder) (NASA, Space Cryogenics Workshop, Madison, WI, June 22, 23, 1987) Cryogenics (ISSN 0011-2275), vol. 28, Feb. 1988, p. 86-89. refs

(Contract NAS2-11879)

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A model has been developed to predict the flow of He II between a source and a receiving dewar. The model uses a finite difference approximation to integrate the describing equations. The transfer path may contain porous plugs or mechanical pumps, heater sections, heat leaks, constrictions due to valves, and bends. These line elements may occur in any order and in any quantity. The line elements are easily reconfigured by changing the input data. The input consists of the number of finite element cells, the pressure in each dewar, the heat input to each section and the dimensions of each section. The output is the temperature, pressure, flow rate, velocities and heat flux in each section. An internal reference table provides the properties of He II. The model is programmed for a LOTUS work sheet. It converges rapidly and usually requires 10 to 15 iterations. For most applications an iteration takes 30 s on an AT. The predictions agree well with experimental data. Author

**A89-44110#**

# **ELECTRIC PROPULSION FOR ORBIT TRANSFER - A CASE STUDY**

JESS M. SPONABLE (USAF, Wright-Patterson AFB, OH) and JAY P. PENN (Aerospace Corp., El Segundo, CA) Journal of Propulsion and Power (ISSN 0748-4658), vol. 5, July-Aug. 1989, p. 445-451. Previously cited in issue 16, p. 2463, Accession no. A87-38001. refs

**A89-46527\*** National Aeronautics and Space Administration, Washington, DC.

# **HISTORICAL OVERVIEW OF THE US USE OF SPACE NUCLEAR POWER**

GARY L. BENNETT (NASA, Propulsion, Power, and Energy Div.,

Washington, DC) (IAF, International Conference on Space Power, Cleveland, OH, June 5-7, 1989) Space Power (ISSN 0951-5089), vol. 8, no. 3, 1989, p. 259-264. refs

(IAF PAPER ICOSP89-9-1) Copyright

Since 1961, the United States has successfully flown 35 space nuclear power sources on 20 space systems. These space systems have included the Apollo, Pioneer, Viking and Voyager spacecraft launched by the National Aeronautics and Space Administration and navigation and communications satellites launched by the Department of Defense. These power sources performed as planned and in many cases exceeded their power requirements and/or lifetimes. All of the power sources met their safety requirements. This paper surveys past uses of space nuclear power in the US and thus serves as a historical framework for other papers in this Conference dealing with future US applications of space nuclear power. Author

**A89-46531**

# **CANDIDATE SPACE MISSIONS FOR NUCLEAR GENERATORS - STUDY RESULTS AND IMPLICATIONS**

CLAUDE POHER (CNES, Paris, France) (IAF, International Conference on Space Power, Cleveland, OH, June 5-7, 1989) Space Power (ISSN 0951-5089), vol. 8, no. 3, 1989, p. 333-337. refs

(IAF PAPER ICOSP89-9-6) Copyright

Since 1982, French government organizations have been collaborating in the study of space nuclear power systems projected to be in orbit after 2005 for European applications in space. This paper examines the feasibility of such systems in Europe, discusses their cost and optimal development procedures, and proposes some choices for different applications. Particular attention is given to the following types of missions: LEO-GEO electric OTV, space-based radars, manned space stations, and planetary exploration. B.J.

**A89-46712\*** Electric Propulsion Lab., Inc., Lancaster, CA.

# **A DETAILED MODEL OF ION PROPULSION SYSTEMS**

JOHN R. BROPHY and GRAEME ASTON (Electric Propulsion Laboratory, Inc., Lancaster, CA) AIAA, ASME, SAE, and ASCE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 15 p. Research sponsored by SDIO. refs

(Contract NAS3-25464)

(AIAA PAPER 89-2268) Copyright

A detailed model for the determination of ion propulsion system masses and performance is presented. The model divides the propulsion system into its component parts and provides mass scaling relationships for each part. In addition, the model is coupled to a detailed ion engine performance model to facilitate investigation of the impact of engine technology assumptions on the overall propulsion system mass and performance. The model is exercised to determine the optimum specific impulse for a selected earth orbit transfer mission. Author

**A89-46726#**

# **ADVANCED LO2/LH2 SPACE ENGINE CHARACTERISTICS**

CHRIS ERICKSON and RON PAUCKERT (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) AIAA, ASME, SAE, and ASCE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p.

(AIAA PAPER 89-2265) Copyright

The geometry, the engine performance characteristics, and the mass of LO2/LH2 engines selected for advanced OTVs are examined as a function of thrust. It is shown that high performance can be achieved with high area ratio nozzles, which are extendable (and retractable) to make it possible to reduce the length of the engine when used with an aerobrake for the earth and Mars entry maneuvers. The nominal throttle ratio is 10:1, and the operating mixture ratio range is 5:1 to 7:1 with a design mixture ratio of 6:1. Potential issues and technology requirements associated with particular design items are discussed. The OTV engine schematic is presented. I.S.

**A89-46780#**

## **A BEAM-POWERED ELECTRIC ORBITAL TRANSFER VEHICLE - THE ADVANTAGES OF NUCLEAR ELECTRIC PROPULSION WITHOUT THE CONCERNS OVER NUCLEAR POWER**

E. P. COOMBS and J. E. DAGLE (Ballistic Pacific Northwest Laboratory, Richland, WA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 12 p. refs

(Contract DE-AC06-76RL-01830)

(AIAA PAPER 89-2372) Copyright

An orbital transfer vehicle (OTV) is described which is a near-term system based on a beam-power satellite employing a growth SP-0100 power source and an OTV employing 200 kW magnetoplasmadynamic thruster. The power beaming concept is described, including the technology options and the prime energy source. The beam-power transmission system is examined, giving an analysis of the aperture diameter product and discussing the transmit and receive options, laser transmitter subsystem, power conversion subsystem, system constraints, and efficiency. The operations and performance of the beam-powered OTV are addressed, and the system sensitivity is discussed. C.D.

**A89-46781#**

## **PRELIMINARY CONCEPTS FOR A SOLAR ELECTRIC ORBIT RAISING EXPERIMENT**

R. B. COHEN, J. P. PENN, S. W. JANSON, D. A. LICHTIN, K. P. ZONDERVAN (Aerospace Corp., Aerophysics Laboratory, El Segundo, CA) et al. AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 12 p.

(AIAA PAPER 89-2373) Copyright

Some preliminary concepts for a solar electric orbit raising demonstration that will show technological readiness for the development of operational Electric Orbital Transfer Vehicles (EOTVs) are outlined. These ideas could serve as a template for the proposed Electric Insertion Transfer Experiment (ELITE). At this moment, ELITE is not a funded program. Concepts are presented for a solar electric orbit raising demonstration, for ELITE, and for the path from the proposed ELITE to a future operational EOTV. A brief discussion of the benefits to be derived from the use of EOTVs, the conceptual organization of the ELITE team, the key technologies for EOTV and ELITE, and some preliminary options for the orbit raising vehicle and representative missions are provided. Author

**A89-46831#**

## **A LIGHT GAS GUN SYSTEM FOR LAUNCHING BUILDING MATERIAL INTO LOW EARTH ORBIT**

JOHN W. HUNTER and ROD A. HYDE (Lawrence Livermore National Laboratory, Livermore, CA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 21 p.

(Contract W-7405-ENG-48)

(AIAA PAPER 89-2439) Copyright

Calculations have been conducted which indicate that the lofting of large quantities of construction materials into LEO can be accomplished through the use of a light gas gun capable of launching tonne-scaled packages, in conjunction with a single-stage rocket that will counteract the effects of atmospheric drag and gravity. This launcher design, which in virtue of its simplicity is reliable and requires low maintenance, will deliver 1-4 tonne masses to terminal velocities in the 7.1-4.7 km/sec range, using conventional, two-stage hydrogen gas gun technology. Over 1000 tonnes will thus be delivered annually into LEO. O.C.

**A89-46870#**

## **ELECTRIC PROPULSION - A NATIONAL CAPABILITY**

J. R. BEATTIE (Hughes Research Laboratories, Malibu, CA) and J. P. PENN (Aerospace Corp., Architecture Planning and Technology Div., El Segundo, CA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. refs

(AIAA PAPER 89-2490) Copyright

The performance advantages of a variety of electric-propulsion

devices for space applications of commercial, military, and scientific interest are described. Highlights of the flight-test and operational experience with mature electric-thruster technologies are mentioned. A review of the development status of electric thrusters in the electrothermal, electrostatic, and electromagnetic categories suggests that low-power ion thrusters and arcjets have been developed and tested to a level that they are now ready for flight use in performing on-orbit stationkeeping. The application of electric thrusters to orbit-raising missions is discussed. Author

**A89-46875#**

## **ELECTRIC ORBITAL TRANSFER VEHICLE - A MILITARY PERSPECTIVE**

S. G. ROSEN and J. H. SLOAN (USAF, Space Systems Div., Los Angeles AFB, CA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 6 p.

(AIAA PAPER 89-2496)

This paper examines the potential of an Electric Orbital Transfer Vehicle (EOTV) from a military perspective. It explores the potential benefits to the military from electric propulsion as well as possible problems with such technology. The Air Force's concept of operations for the launching of satellites and the question of vulnerability of an EOTV in time of war are also considered. Issues associated with transferring a new technology into the operational world of the Air Force is also discussed. Author

**A89-46885#**

## **UTILITY PROPULSION FOR THE SPACE STATION ERA**

L. W. HOBBS (British Aerospace (Space Systems), Ltd., Stevenage, England) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 7 p.

(AIAA PAPER 89-2508) Copyright

This paper discusses an approach to spacecraft propulsion which differs from the traditional approach of 'design for purpose' which is typical of the propulsion systems incorporated into today's spacecraft. The design approach presented here is to configure a propellant feed module which can be used without modification in a wide variety of applications. This is achieved by multiple connection of modules to furnish a given impulse requirement. Main engines and reaction control thruster modules are added to the feed as required. The aim of the approach is to reduce the overall cost of in-orbit propulsion by mass production means and provide a utility standard around which further vehicles and applications can be structured without the significant nonrecurring costs currently associated with new developments. C.D.

**A89-46913#**

## **ACHIEVING PRACTICAL SPACE PROPULSION THROUGH STORAGE OF SOLAR ENERGY**

MICHAEL E. LISANO (Auburn University, AL) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 6 p.

(AIAA PAPER 89-2544) Copyright

The conceptual design of a space engine that derives its thrust from stored thermal energy is discussed. Central to this approach is the ability of certain materials to store large quantities of energy in their 'sensible' and latent thermal properties. Typical materials are LiH, Be, Si, and a host of salts. A model of the engine is developed, and its performance is analyzed for a number of storage materials. Particular attention is paid to free space Delta-v and specific impulse. The results of analysis are discussed in terms of potential applications of the engine design. Author

**A89-46948#** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

## **BASLINE SPACECRAFT AND MISSION DESIGN FOR THE SP-100 FLIGHT EXPERIMENT**

WILLIAM D. DEININGER (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) and ROBERT J. VONDRA (W. J. Schafer Associates, Inc., Arlington, VA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 14 p. Research sponsored by SDIO. refs

(AIAA PAPER 89-2594) Copyright

The design and performance of a spacecraft employing arcjet nuclear electric propulsion, suitable for use in the SP-100 Space Reactor Power System (SRPS) Flight Experiment, are outlined. The vehicle design is based on a 93 kW ammonia arcjet system operating at an experimentally-measured specific impulse of 1030 s and an efficiency of 42 percent. The arcjet/gimbal assemblies, power conditioning subsystem, propellant feed system, propulsion system thermal control, spacecraft diagnostic instrumentation, and the telemetry requirements are described. A 100 kW SRPS is assumed. The total spacecraft mass is baselined at 5675 kg excluding the propellant and propellant feed system. Four mission scenarios are described which are capable of demonstrating the full capability of the SRPS. The missions considered include spacecraft deployment to possible surveillance platform orbits, a spacecraft storage mission and an orbit raising round trip corresponding to possible orbit transfer vehicle missions. Launches from Kennedy Space Center using the Titan IV expendable launch vehicle are assumed. *Author*

**A89-46960\*** McDonnell-Douglas Astronautics Co., Huntington Beach, CA.

#### DESIGN, OPERATION, AND CRITICAL ISSUES OF THE U.S. SPACE STATION FREEDOM PROPULSION SYSTEM

JOSEPH S. MORANO (McDonnell Douglas Space Systems Co., Space Station Div., Huntington Beach, CA) and JOHN B. HENDERSON (NASA, Johnson Space Center, Houston, TX) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 11 p. (AIAA PAPER 89-2611)

The U.S. Space Station Freedom Manned Base (SSFMB) propulsion system is a gaseous hydrogen/oxygen-based system for primary reboost, attitude control, and station contingencies using electrolyzed water as a propellant. A secondary propulsion reboost system employs multipropellant resistojets which utilize the various waste gases generated during normal station operations. The hydrogen/oxygen propulsion system is comprised of several modules which contain thrusters, propellant storage tanks, regulation subsystems, water electrolysis units, electronic controls, and fluid plumbing. The resistojets system is comprised of one module containing the resistojets, regulators, electronic controls, and fluid plumbing. The waste gas propellant storage takes place in the Fluid Management System. *Author*

**A89-46961\*** Ford Aerospace Corp., Reston, VA.  
PROPULSION ELEMENT REQUIREMENTS USING ELECTRICAL POWER SYSTEM UNSCHEDULED POWER  
FRANK ZIMMERMANN (Ford Aerospace Corp., Reston, VA) and KATHY HODGE (NASA, Space Station Freedom Program Office, Reston, VA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 7 p. (AIAA PAPER 89-2612) Copyright

The suitability of using the electrical energy from the Space Station's Electrical Power System (EPS) during the periods of peak solar insolation which is currently not specifically allocated (unscheduled power) to produce propulsion propellants, gaseous hydrogen, and oxygen by electrolyzing water is investigated. Reboost propellant requirements are emphasized, but the results are more generally relevant because the balance of recurring propellant requirements are an order of magnitude smaller and the nonrecurring requirements are not significant on an average basis. *C.D.*

**A89-46962\*** McDonnell-Douglas Astronautics Co., Huntington Beach, CA.

#### A MODULAR PROPULSION SYSTEM REQUIRED FOR SPACE STATION ASSEMBLY

JOSEPH S. MORANO (McDonnell Douglas Space Systems Co., Space Station Div., Huntington Beach, CA) and JOHN B. HENDERSON (NASA, Johnson Space Center, Houston, TX) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 9 p. (AIAA PAPER 89-2613)

The U.S. Space Station Freedom Manned Base will be

assembled on-orbit over the course of several years and multiple Space Shuttle flights. This paper discusses the assembly sequence evolution and its effects on the propulsion system. Relevant descriptions and parameters are given for the gaseous propellant storage, thruster quantity and orientation, and resistojets module. Specific assembly sequences are described and their most important characteristics are compared. *C.D.*

**A89-46963\*** National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, AL.

#### SPACE STATION PROPULSION - ADVANCED DEVELOPMENT TESTING OF THE WATER ELECTROLYSIS CONCEPT AT MSFC

LEE W. JONES and DEBORAH R. BAGDIGIAN (NASA, Marshall Space Flight Center, Huntsville, AL) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 19 p. (AIAA PAPER 89-2615) Copyright

The successful demonstration at Marshall Space Flight Center (MSFC) that the water electrolysis concept is sufficiently mature to warrant adopting it as the baseline propulsion design for Space Station Freedom is described. In particular, the test results demonstrated that oxygen/hydrogen thruster, using gaseous propellants, can deliver more than two million lbf-seconds of total impulse at mixture ratios of 2:1 to 8:1 without significant degradation. The results also demonstrated successful end-to-end operation of an integrated water electrolysis propulsion system. *C.D.*

**A89-46964\*** National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, TX.

#### SPACE STATION PROPULSION ELECTROLYSIS SYSTEM - 'A TECHNOLOGY CHALLENGE'

MICHAEL LE (NASA, Johnson Space Center, Houston, TX) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 11 p. refs. (AIAA PAPER 89-2616) Copyright

The Space Station propulsion system will utilize a water electrolysis system to produce the required eight-to-one ratio of gaseous hydrogen and oxygen propellants. This paper summarizes the state of the art in water electrolysis technologies and the supporting development programs at the NASA Lyndon B. Johnson Space Center. Preliminary proof of concept test data from a fully integrated propulsion testbed are discussed. The technical challenges facing the development of the high-pressure water electrolysis system are discussed. *C.D.*

**A89-46965\*** National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, TX.

#### SPACE SHUTTLE ORBITER MAIN PROPULSION SYSTEM FLIGHT SAFETY ENHANCEMENT

PHILLIP E. COTA (NASA, Johnson Space Center, Houston, TX) and DONALD L. JONES (Rockwell International Corp., Space Transportation Systems Div., Downey, CA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 9 p. (AIAA PAPER 89-2619) Copyright

The Space Shuttle main propulsion system, like other major elements of the vehicle, has been part of an ongoing program to enhance the flight safety of the Space Transportation System. This activity, inherent in the basic program since its inception, has continued as part of a renewed review of failure modes and effects pertaining to flight-critical functions. Selected components were further evaluated, their potential for impacting flight safety was defined, and then the necessity for changing their design and/or operational practices was determined. Major examples of such components are the 17-inch disconnect and gaseous oxygen flow control valve. This paper summarizes that activity and provides examples of critical processes and components that have been or are being modified to enhance flight safety. *Author*



**A89-47048#**

## **AUTOMATIC REFUELING COUPLING FOR ON-ORBIT SPACECRAFT SERVICING**

WILLIAM HAMILTON (Fairchild Control Systems Co., Manhattan Beach, CA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. (AIAA PAPER 89-2731) Copyright

This paper presents a description of an automatic refueling coupling that was specially designed for on-orbit refueling of space vehicles. The coupling meets all NASA safety requirements for the safe handling of hydrazine. The coupling is suitable for use on automated resupply mechanisms. Author

**A89-47060#**

## **LOW COST DESIGN APPROACHES FOR THE ADVANCED LAUNCH SYSTEM (ALS) PROPULSION SYSTEM**

R. D. MCKOWN (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 17 p. (AIAA PAPER 89-2749) Copyright

The goals for the ALS are to reduce the cost of payloads to low earth orbit by a factor of ten compared to the existing Space Shuttle vehicle. This objective translates directly to all parts of the launch hardware and support systems. The manufacturer has met this challenge by designing an engine system which can be produced at less than one-tenth the cost of the current Space Shuttle Main Engine and which is suitable, with modifications, for use as either a main engine or booster engine. This paper identifies and quantifies the design approach taken to achieve these low cost objectives. Author

**A89-47115\*#** Booz-Allen and Hamilton, Inc., Reston, VA.

## **SENSITIVITY OF PROPULSION SYSTEM SELECTION TO SPACE STATION FREEDOM PERFORMANCE REQUIREMENTS**

GEORGE R. SCHMIDT (Booz-Allen and Hamilton, Inc., Reston, VA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 12 p. refs (Contract NASW-4300) (AIAA PAPER 89-2835) Copyright

The selection of the propulsion system for the Space Station (SS) is reassessed. The propulsion system consists of two distinct elements. The first of these combusts gaseous oxygen and hydrogen produced from water electrolysis, to maintain the SS altitude and perform higher thrust maneuvers for backup attitude control, collision avoidance, and other contingencies. The second consists of gas resistojets, which augment attitude maintenance. The results of a parametric comparison of the life cycle costs of this electrolysis/resistojets propulsion with those of other system options, carried out over a range of probable performance requirements, confirmed the baseline superiority of the SS propulsion system for most anticipated conditions. However, relative costs among impulse requirements vary so much that major changes in the design conditions may warrant implementation of another system (such as hydrazine with water resistojets). I.S.

**A89-47119\*#** National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, AL.

## **CRYOGENIC FLUID MANAGEMENT TECHNOLOGY REQUIREMENTS FOR THE SPACE TRANSFER VEHICLE**

JOHN M. CRAMER and NORMAN S. BROWN (NASA, Marshall Space Flight Center, Huntsville, AL) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. refs (AIAA PAPER 89-2843) Copyright

An in-house study was performed to design a cryogenic Space Transfer Vehicle (STV) for the late 1990s that can evolve with the demanding mission requirements of the manned exploration initiatives. An assessment of cryogenic fluid management technology issues associated with the STV was performed to identify technology gaps and propose advanced development activities. Author

**A89-47122\*#** Massachusetts Inst. of Tech., Cambridge.

## **VAPOR CONDENSATION AT A TURBULENT LIQUID SURFACE IN SYSTEMS WITH POSSIBLE SPACED-BASED APPLICATIONS**

J. S. BROWN, M. R. HELMICK, and A. A. SONIN (MIT, Cambridge, MA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 13 p. refs (Contract NAG3-731) (AIAA PAPER 89-2846) Copyright

Brown and Sonin's (1989) correlation is used to predict the condensation rate in three different systems and the results are compared with experimental data. These systems are: (1) a cylindrical system with turbulent mixing provided by an axial submerged jet, (2) a channel flow with grid-induced turbulence, and (3) a swirling film flow in a cylinder. The first and third system are of interest for space applications. While all the present data are from ground-based laboratory tests, the comparisons are restricted to conditions of low Richardson number, where the local condensation rate per unit area at the liquid surface is not affected by buoyancy effects. K.K.

**A89-47129#**

## **PROPULSION SYSTEM FOR AN INTERNATIONAL SPACE STATION LOGISTIC VEHICLE**

YVES COSTE, CHRISTOPHE BONNAL, and MAX CALABRO (Aerospatiale, Les Mureaux, France) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 11 p. refs (AIAA PAPER 89-2857) Copyright

This paper presents the main results of a trade-off about the propulsion systems suitable with an expandable launch vehicle for Space Station Freedom servicing. Their designing rules are established with regard to safety and mission requirements. In conclusion, the more convenient system consists of a bipropellant (N2H4-N2O4) main subsystem with a monopropellant attitude control system and a cold gas system, for mass and cost reasons. This job was done in the frame of ESA activities. Author

**A89-47132#**

## **USE OF MAGNETIC SAILS FOR MARS EXPLORATION MISSIONS**

DANA G. ANDREWS (Boeing Aerospace, Seattle, WA) and R. M. ZUBRIN (Martin Marietta Corp., Denver, CO) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. refs (AIAA PAPER 89-2861) Copyright

The use of a novel propulsion system, the magnetic sail (or magsail), for Mars exploration missions is described. This sail propels spacecraft by using the magnetic field generated by a loop of superconducting cable to deflect interplanetary winds. In effect, it produces an order of magnitude more acceleration than the solar sail on a pound for pound basis. A comparison is made between the performance of a Mars spacecraft utilizing conventional chemical and electric propulsion systems and a Mars spacecraft utilizing a magsail 64 km in diameter and generating an average thrust of 500 Newtons at a radius of 1 A.U. K.K.

**A89-47426**

## **INTERNATIONAL ELECTRIC PROPULSION CONFERENCE, 20TH, GARMISCH-PARTENKIRCHEN, FEDERAL REPUBLIC OF GERMANY, OCT. 3-6, 1988, PROCEEDINGS**

Conference sponsored by DGLR, AIAA, and Japan Society of Aeronautical and Space Sciences, Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1988, 740 p. For individual items see A89-47427 to A89-47474, A89-47476 to A89-47513. (DGLR BERICHT 88-02)

Papers are presented on the development of electrical propulsion, problems involved in the implementation of electrical propulsion, theoretical and experimental studies on magnetoplasmadynamic (MPD) thrusters, interactions of power sources and plasmas, and field emission electric propulsion. Also considered are ion thruster flight tests, power conditioning and control, auxiliary propulsion systems, applied-field MPD thrusters,

experimental missions, and electrode processes. Other topics include advanced systems, primary ion propulsion, plasma and plume phenomena, microwave devices, arcjets, thruster-spacecraft interactions, and nonpropulsive applications. R.R.

#### AB9-47427#

##### THE ESA POLICY AND PROGRAMME FOR THE DEVELOPMENT OF ELECTRIC PROPULSION

W. BERRY, C. BARTOLI, and A. TRIPPI (ESA, Technical Directorate, Noordwijk, Netherlands) IN: International Electric Propulsion Conference, 20th, Garmisch-Partenkirchen, Federal Republic of Germany, Oct. 3-6, 1988, Proceedings, Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1988, p. 5-16. refs

The constraints and mission priorities of the ESA electric propulsion program are reviewed, with special attention given to the advantages of electric propulsion for four applications: (1) north-south stationkeeping of geostationary satellites; (2) orbit maneuvering and maintenance of such large low-orbiting spacecraft as Columbus and the Man-Tended Free Flyer; (3) primary propulsion for interplanetary missions; and (4) fine-pointing and attitude and orbit control of scientific satellites. Current aspects of the ESA program considered include the testing of a multipropellant rocket for a manned space station, the testing of a 15-kW arcjet for satellite maintenance and orbit maneuvering, and final preparation of the RITA ion engine for the Eureka carrier. Also considered are the development of an ion propulsion system (to be used for the SAT-2 satellite) and a field emission electric propulsion system. R.R.

AB9-47428# National Aeronautics and Space Administration, Washington, DC.

##### THE NASA ELECTRIC PROPULSION PROGRAM

JAMES R. STONE (NASA, Office of Aeronautics and Space Technology, Washington, DC), DAVID C. BYERS (NASA, Lewis Research Center, Cleveland, OH), and DAVID Q. KING (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: International Electric Propulsion Conference, 20th, Garmisch-Partenkirchen, Federal Republic of Germany, Oct. 3-6, 1988, Proceedings, Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1988, p. 17-25. Previously announced in STAR as N88-29859. refs

The NASA OAST Propulsion, Power, and Energy Division supports an electric propulsion program aimed at providing benefits to a broad class of missions. Concepts which have the potential to enable or significantly benefit space exploration and exploitation are identified and advanced toward application in the near and far term. This paper summarizes recent program progress in mission/system analysis; in electrothermal, electrostatic, and electromagnetic propulsion technologies; and in propulsion/spacecraft integration. Author

#### AB9-47429#

##### ELECTRIC PROPULSION PROJECTS AND RESEARCHES IN JAPAN

KYOICHI KURIKI (Institute of Space and Astronautical Science, Sagami, Japan) and YOSHIHIRO NAKAMURA (National Aerospace Laboratory, Chofu, Japan) IN: International Electric Propulsion Conference, 20th, Garmisch-Partenkirchen, Federal Republic of Germany, Oct. 3-6, 1988, Proceedings, Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1988, p. 26-36. refs

Japanese activities related to the development of electric propulsion systems are reviewed, with emphasis on the tailoring of design goals to fulfill present and future mission power requirements. Plasma propulsion projects discussed include the 1-kW magnetoplasmadynamic (MPD) thruster system being developed for the electric propulsion experiment to be flown aboard the Space Flyer Unit (SFU), a two-dimensional MPD arcjet to study MPD flowfields, a laser propulsion system experiment (to be flown aboard the SFU) which involves CW-type to repetitively-pulsed-type laser thrusters, and electrodeless electrothermal thrusters. Also considered are ion propulsion systems for the Engineering Test Satellite VI. R.R.

#### AB9-47434#

##### ELECTRIC PROPULSION FOR LOW EARTH ORBIT APPLICATIONS

M. ANDRENUCCI (Pisa, Università, Italy) and A. TRIPPI (ESA, Technical Directorate, Noordwijk, Netherlands) IN: International Electric Propulsion Conference, 20th, Garmisch-Partenkirchen, Federal Republic of Germany, Oct. 3-6, 1988, Proceedings, Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1988, p. 62-68. refs

The paper presents a discussion on the novel opportunities of application of electric propulsion (EP) systems arising from the anticipated expansion of LEO activities. First, the inherent characteristics and performance capability of EP systems are assessed. It is shown that the various thruster concepts should not be regarded as alternative options to be traded off, but rather as a set of answers to future propulsion needs, complementary in nature and graduated in time. The paper then lists a variety of potential applications related to near-earth activities: orbit maintenance, drag cancellation, and orbit raising to polar orbit and back. A more specific example is discussed concerning a man-tended-free-flyer type microgravity laboratory. Author

AB9-47437# Jet Propulsion Lab., California Inst. of Tech., Pasadena.

##### SPACECRAFT AND MISSION DESIGN FOR THE SP-100 FLIGHT EXPERIMENT

WILLIAM D. DEININGER (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) and ROBERT J. VONORA (W. J. Schafer Associates, Inc., Arlington, VA) IN: International Electric Propulsion Conference, 20th, Garmisch-Partenkirchen, Federal Republic of Germany, Oct. 3-6, 1988, Proceedings, Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1988, p. 86-98. Research sponsored by SDIO. refs

The design and performance of a spacecraft employing arcjet nuclear-electric propulsion, suitable for use in the SP-100 space-reactor power-system (SRPS) flight experiment, are outlined. The vehicle design is based on a 93-kWe ammonia arcjet system operating at an experimentally measured specific impulse of 1031 sec and an efficiency of 42.3 percent. The arcjet/gimbal assemblies, power conditioning subsystem, propellant feed system, propulsion system thermal control, spacecraft diagnostic instrumentation, and the telemetry requirements are described. A 100-kWe SRPS is assumed. The spacecraft mass is baselined at 5675 kg, excluding the propellant and propellant feed system. Four mission scenarios are described which are capable of demonstrating the full capability of the SRPS. Author

#### AC9-47438#

##### DEVELOPMENT OF AN MPD PROPULSION SYSTEM

Y. SHIMIZU, K. TOKI, and K. KURIKI (Institute of Space and Astronautical Science, Sagami, Japan) IN: International Electric Propulsion Conference, 20th, Garmisch-Partenkirchen, Federal Republic of Germany, Oct. 3-6, 1988, Proceedings, Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1988, p. 99-104. refs

A 1-kW MPD thruster system developed at ISAS recorded 3 x 10 to the 6th accumulated firings, which correspond to 25 days continuous operation demonstrating 34 mN/kW at an Isp of 600 sec. The critical components for system endurance, an MPD thruster head of segmented electrodes and a 574-J fail-proof capacitor bank were placed in a vacuum chamber to be operated in 1.4-Hz repetitively pulsed quasi-steady mode. Software for automatic control of firings and system diagnosis was also successfully verified without human manipulation for hold and restart. The system was qualified as a breadboard model for Epex (Electric Propulsion Experiment) on the SFU (Space Flyer Unit) (launch scheduled in the early 1990s). Author

#### AB9-47459#

##### VERIFICATION OF PERFORMANCE AND ENDURANCE OF CAPACITOR BANK FOR THE ELECTRIC PROPULSION EXPERIMENT (EPEX)

Y. KUNII, M. SUMIDA, T. MORI, H. SASAKI, T. OKAMURA

(Mitsubishi Electric Corp., Kamakura Works, Japan) et al. IN: International Electric Propulsion Conference, 20th, Garmisch-Partenkirchen, Federal Republic of Germany, Oct. 3-6, 1988, Proceedings. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1988, p. 292-299. refs

The Electric Propulsion Experiment (Epex) is a Japanese space experiment program for the quasi-steady MPD (magnetoplasmadynamic) propulsion system. The Epex is planned to be conducted on a Japanese free-flying platform in the 1990s. The design requirements and the results of the 1987 ground test are summarized in this paper for the capacitor bank in the power conversion subsystem. The power-conversion efficiency in the pulse-forming network was found to be approximately 85 percent in the ground test. The number of repetitive discharges amounted to 3 million in an operation period of 25 days. Author

A89-47460#

#### VERIFICATION OF CONTROL SEQUENCE AND ALGORITHM FOR THE ELECTRIC PROPULSION EXPERIMENT (EPEX)

M. SUMIDA, Y. KUNII, T. MORI, T. OKAMURA, T. YOSHIDA (Mitsubishi Electric Corp., Kamakura Works, Japan) et al. IN: International Electric Propulsion Conference, 20th, Garmisch-Partenkirchen, Federal Republic of Germany, Oct. 3-6, 1988, Proceedings. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1988, p. 300-305.

The Electric Propulsion Experiment (Epex) is a Japanese space experiment program for the quasi-steady MPD (magnetoplasmadynamic) propulsion system. The Epex is planned to be conducted on a Japanese free-flying platform in the 1990s. The control and monitor system, based on a microcomputer, was successfully operated repetitive discharges of 3 million shots in an operation period of 25 days, even though the hardware of the control and monitor system was composed of equipment for general ground use. The successful operation verified the basic control logic for the MPD propulsion system. Based on the test results, the conceptual design and requirements for the control and monitor subsystem were refined. The monitor signals were evaluated and selected for the flight system. Author

A89-47470#

#### ELECTRICAL TRANSFER VEHICLE ANALYSIS FOR FUTURE SPACE OPERATIONS (MESCATS)

W. KLEINAU, D. E. KOELLE, and W. MUELLER (Messerschmitt-Boelkow-Loeb GmbH, Munich, Federal Republic of Germany) IN: International Electric Propulsion Conference, 20th, Garmisch-Partenkirchen, Federal Republic of Germany, Oct. 3-6, 1988, Proceedings. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1988, p. 383-390.

A modular orbital transfer vehicle for scientific and cargo transportation mission, called MESCATS, has been investigated, in particular, for advanced transportation between operational bases in a geostationary orbit as well as in a lunar orbit. A cluster of electrical ion-thrusters (RIT 35) recently under development tests, has been considered as the main propulsion system. Due to its high specific impulse (up to 38,000 Nsec/kg) MESCATS an interesting candidate providing not only high delta velocity increments but being also especially economic also for cargo missions (earth/moon) due to its lower propellant demand, compared to chemical orbital transfer vehicles. As the analysis has shown, it appears feasible to develop an electrical OTV-like MESCATS which could meet a wide range of operational requirements (such as payload mass, orbital transfer time, velocity increment), with key elements assumed to be available in Europe in the medium-term future. Author

A89-47503

#### DIAGNOSTIC TOOLS FOR AN ION THRUSTER IN SPACE

G. L. WRENN, K. A. RYDEN, D. G. FEARN (Royal Aerospace Establishment, Farnborough, England), A. R. MARTIN, P. M. LATHAM (Culham Laboratory, Abingdon, England) et al. IN: International Electric Propulsion Conference, 20th, Garmisch-Partenkirchen, Federal Republic of Germany, Oct. 3-6,

1988, Proceedings. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1988, p. 634-638. refs

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The prospects for a wider utilization of ion propulsion are outlined as a prerequisite for assessing their possible impact upon spacecraft systems. A manifest is made of all effects which could be detrimental to spacecraft or payload performance and each is examined in terms of the probable risk and available safeguards. In-flight monitoring of the effects will be essential to demonstrate the viability of any particular ion thruster unit and various diagnostic instruments are discussed. Computer simulation provides a valuable tool for estimating plasma interaction effects and some initial results from NASCAP are presented. Problem areas are identified and solutions proposed. In some cases, special measuring techniques are being developed, and these are described in outline. Author

A89-47508#

#### THE USE OF ELECTRIC PROPULSION TECHNIQUES FOR LEO ATOMIC OXYGEN SIMULATION

J. P. W. STARK (Southampton, University, England) and M. A. KINNEERSLEY IN: International Electric Propulsion Conference, 20th, Garmisch-Partenkirchen, Federal Republic of Germany, Oct. 3-6, 1988, Proceedings. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1988, p. 674-680. Research supported by SERC; Ministry of Defence. refs (Contract MOD-GR/E/07166)

Orbiting space vehicles operating at altitudes below 1000 km are subject to impact by atmospheric species. Within the altitude range between 100 to 900 km the dominant species is atomic oxygen (O<sup>1</sup>). The velocity of the vehicle through this atmosphere results in an impact velocity of 8 km/s. The flux (altitude sensitive) is typically 10 to the 15th atoms/sq cm within the shuttle orbit. Electric propulsion techniques, yielding velocities of the same order are thus appropriate for sources attempting to simulate the LEO environment. Discussion of the Southampton Arc jet atomic oxygen source and its performance are covered, with particular relevance to improving atomic oxygen flux and velocity. Author

A89-47510#

#### KREM - A MODEL FOR EVALUATING ORBITAL TRANSFER VEHICLES UTILIZING NUCLEAR ELECTRIC PROPULSION SYSTEMS

W. F. LYON (Texas A & M University, College Station) IN: International Electric Propulsion Conference, 20th, Garmisch-Partenkirchen, Federal Republic of Germany, Oct. 3-6, 1988, Proceedings. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1988, p. 687-692. refs

A computer model, designated KREM, designed for evaluating the performance of spacecraft designs that utilize nuclear electric propulsion systems is described. The KREM code features an interactive input environment for which the user can specify the parameters available for the characterization of a given mission study; the code includes empirical models for an argon magnetoplasmadynamic (MPD) and a hydrogen arc-jet thruster system. The operation of KREM was evaluated by analyzing a spacecraft performance for a reference low-earth orbit to geosynchronous orbit mission, conducted for both the MPD and arc-jet thruster systems. I.S.

A89-48588#

#### IMPACT OF WATER INTEGRATION ON SPACE STATION FREEDOM PROPELLANT AVAILABILITY

GEORGE R. SCHMIDT (Booz, Allen and Hamilton, Inc., Reston, VA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 26, July-Aug. 1989, p. 259-265. Previously cited in issue 20, p. 3275, Accession no. A87-45259. (Contract NAS8-36526)

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A89-48609

#### HANDLING OF FLUIDS IN MICROGRAVITY USING INDUCED ROTATION (HANDHABUNG VON FLUIDEN IN DER SCHWERELOSIGKEIT MITTELS INDUZIERTER ROTATION)



ANTONIO DELGADO and HANS J. RATH (Bremen, Universität, Federal Republic of Germany) (Gesellschaft fuer angewandte Mathematik und Mechanik, Wissenschaftliche Jahrestagung, Vienna, Austria, Apr. 5-9, 1988) Zeitschrift fuer angewandte Mathematik und Mechanik (ISSN 0044-2267), vol. 68, no. 6, 1988, p. T 614-T 616. In German. refs

Copyright

This paper analyzes the use of a disk stirrer at low Reynolds numbers to handle fluids in microgravity by induced rotation. A mathematical analysis based on the linearization of the Navier-Stokes equations is presented. The equations are solved using a similarity ansatz. C.D.

**A89-50811\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

#### PERFORMANCE CHARACTERIZATION AND TRANSIENT INVESTIGATION OF MULTIPROPELLANT RESISTOJETS

EDWARD P. BRAUNSCHEIDEL (NASA, Lewis Research Center, Cleveland, OH) AIAA, ASME, SAE, and ASCE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-12, 1989. 20 p. Previously announced in STAR as N89-25283. refs (AIAA PAPER 89-2837) Copyright

The multipropellant resistojet thruster design initially was characterized for performance in a vacuum tank using argon, carbon dioxide, nitrogen, and hydrogen, with gas inlet pressures ranging from 13.7 to 310 kPa (2 to 45 psia) over a heat exchanger temperature range of ambient to 1200 C (2200 F). Specific impulse, the measure of performance, had values ranging from 120 to 600 seconds for argon and hydrogen respectively, with a constant heat exchanger temperature of 1200 C (2200 F). When operated under ambient conditions typical specific impulse values obtained for argon and hydrogen ranged from 55 to 290 seconds, respectively. Performance measured with several mixtures of argon and nitrogen showed no significant deviation from predictions obtained by directly weighting the argon and nitrogen individual performance results. Another aspect of the program investigating transient behavior, showed responses depended heavily on the start-up scenario used. Steady state heater temperatures were achieved in 20 to 75 minutes for argon, and in 10 to 90 minutes for hydrogen. Steady state specific impulses were achieved in 25 to 60, and 20 to 60 minutes, respectively. Author

**A89-50814\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

#### WEIGHT SAVINGS IN AEROSPACE VEHICLES THROUGH PROPELLANT SCAVENGING

STEVEN J. SCHNEIDER and BRIAN D. REED (NASA, Lewis Research Center, Cleveland, OH) SAWE, Annual Conference, 47th, Plymouth, MI, May 23-25, 1988. 41 p. Previously announced in STAR as N88-25470. refs (SAWE PAPER 1818) Copyright

Vehicle payload benefits of scavenging hydrogen and oxygen propellants are addressed. The approach used is to select a vehicle and a mission and then select a scavenging system for detailed weight analysis. The Shuttle 2 vehicle on a Space Station rendezvous mission was chosen for study. The propellant scavenging system scavenges liquid hydrogen and liquid oxygen from the launch propulsion tankage during orbital maneuvers and stores them in well insulated liquid accumulators for use in a cryogenic auxiliary propulsion system. The fraction of auxiliary propulsion propellant which may be scavenged for propulsive purposes is estimated to be 45.1 percent. The auxiliary propulsion subsystem dry mass, including the proposed scavenging system, an additional 20 percent for secondary structure, an additional 5 percent for electrical service, a 10 percent weight growth margin, and 15.4 percent propellant reserves and residuals is estimated to be 6331 kg. This study shows that the fraction of the on-orbit vehicle mass required by the auxiliary propulsion system of this Shuttle 2 vehicle using this technology is estimated to be 12.0 percent compared to 19.9 percent for a vehicle with an earth-storable bipropellant system. This results in a vehicle with the capability of delivering an additional 7820 kg to the Space Station. Author

**A79-51143**

#### A MINIATURE CRYOGENIC QUARTZ CRYSTAL MONITOR (QCM) FOR MEASURING CONTAMINATION OF OPTICAL SURFACES ON SPACECRAFT

DONALD A. WALLACE and SCOTT A. WALLACE (QCM Research, Laguna Beach, CA) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1988, p. 637-646. refs

Copyright

A miniature quartz crystal microbalance (mQCM), called the MK 16 QCM Sensor, is fully described in terms of its temperature range (5 to 360 K), its ability to raise the temperature of the crystals independently of the case (which is held at about 10 K) with only 1.5 watts of power, and be designed as a flight qualified unit. As a QCM sensor, the MK 16 not only measures the mass of contaminants that arrive with time (8.7 Hz per monolayer) but also by raising the temperature of the crystal, constituent gases will be reemitted from the crystal which can be further analyzed by QCM thermogravimetry. Author

**A89-52681\***

#### AN ON-ORBIT CONTROL LAW FOR THE MATED OMV AND SHUTTLE-C

WILLIAM P. MAGGARD (Control Dynamics Co., Huntsville, AL) IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 2, Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1456-1464. refs

(AIAA PAPER 89-3603) Copyright

A control law for remotely piloted rendezvous and docking operations with the mated OMV (Orbital Maneuvering Vehicle) and the proposed unmanned space cargo transportation vehicle (Shuttle-C) is presented. The sensitivity of this control law to variations in the vehicle CM (center of mass), principle axis inclination, and payload mass is evaluated by means of a 6 DOF (degree of freedom) digital computer simulation of the system. Conclusions regarding the robustness of the control law and the feasibility of the vehicle configuration are presented. Author

**A89-52682\***

#### ORBITAL MANEUVERING VEHICLE ATTITUDE CONTROL SYSTEM

PAUL G. PARRY, ALEX D. GOLUB, and DANA M. SOUTHWOOD (TRW, Inc., TRW Space and Technology Group, Redondo Beach, CA) IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 2, Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1465-1475.

(AIAA PAPER 89-3604) Copyright

The NASA/TRW Orbital Maneuvering Vehicle (OMV) will be one of the most versatile spacecraft ever built. Designed to extend the reach of the Space Shuttle, the OMV will be required to perform orbit transfers and proximity operations both alone and with payloads of various sizes. It will be able to rendezvous, dock with, and retrieve or deploy other spacecraft, using both automatic and remote man-in-the-loop techniques. Its multiple mission and operational requirements place a heavy burden on the attitude control system (ACS), which must be equally versatile to be successful. The ACS is being designed to operate in four distinct operational modes, during which three separate propulsion systems are utilized by two distinct control laws to perform any attitude control task required of the OMV. The preliminary designs of these two control laws have been evaluated by both linear stability analysis and nonlinear simulation. Author

**N89-20173\*** Auburn Univ., AL. Dept. of Aerospace Engineering.

#### UNMANNED, SPACE-BASED, REUSABLE ORBITAL TRANSFER VEHICLE, DARVES, VOLUME 1: TRADE ANALYSIS AND DESIGN Final Report

Jun. 1988 54 p

## 09 PROPULSION/FLUID MANAGEMENT

(Contract NGT-21-002-080)  
(NASA-CR-184711; NAS 1.26:184711) Avail: NTIS HC A04/MF A01 CSCL 22B

The design of an unmanned, space-based, reusable Orbital Transfer Vehicle (OTV) is presented. This OTV will be utilized for the delivery and retrieval of satellites from geosynchronous Earth orbit (GEO) in conjunction with a space station assumed to be in existence in low Earth orbit (LEO). The trade analysis used to determine the vehicle design is presented, and from this study a vehicle definition is given. Author

**N89-20174\*** Auburn Univ., AL. Dept. of Aerospace Engineering.

### UNMANNED, SPACE-BASED, REUSABLE ORBITAL TRANSFER VEHICLE, DARYS. VOLUME 2: DATA AND CALCULATIONS Final Report

Jun. 1988 37 p  
(Contract NGT-21-002-080)  
(NASA-CR-184712; NAS 1.26:184712) Avail: NTIS HC A03/MF A01 CSCL 22B

Results for trajectory analysis, fuel analysis, and analysis of aerobraking maneuvers are presented. Calculations are included for thickness and mass of the propellant tanks; determination of weight (avionics module); numerical integration program; hydrostatic pressure due to acceleration; and propellant tank pressurization. B.G.

**N89-20175\*** Virginia Univ., Charlottesville. WWSR, Inc. TWO DESIGNS FOR AN ORBITAL TRANSFER VEHICLE: A COMPARISON OF TWO OTVS Summary Report

1988 19 p Presented at the NASA/USRA Advanced Design Program Summer Conference, Jun. 1988  
(Contract NGT-21-002-090)  
(NASA-CR-184696; NAS 1.26:184696; REPT-1) Avail: NTIS HC A03/MF A01 CSCL 22B

The basic components of the design for the orbital transfer vehicle (OTV) are outlined. The Project Orion and the MOVERS OTV design are compared. The nature of the work and the specifics will be reviewed. The propellant systems are summarized along with the dollar savings. The strengths and weaknesses are highlighted for each OTV. B.G.

**N89-20176\*** Virginia Univ., Charlottesville. WWSR, Inc. TWO DESIGNS FOR AN ORBITAL TRANSFER VEHICLE. PROJECT ORION: A PROPOSAL FOR A MANNED ORBITAL TRANSFER VEHICLE FOR THE 21ST CENTURY

1988 129 p Presented at the NASA/USRA Advanced Design Program Summer Conference, Jun. 1988  
(Contract NGT-21-002-080)  
(NASA-CR-184697; NAS 1.26:184697; REPT-2) Avail: NTIS HC A07/MF A01 CSCL 22B

The most optimal design for a chemical propellant, manned OTV that fulfills the described constraints is presented. The design of the Project Orion OTV and its subsystems are examined. B.G.

**N89-20177\*** Virginia Univ., Charlottesville. Modular Orbital Vehicle Engineering Research Society.

### TWO DESIGNS FOR AN ORBITAL TRANSFER VEHICLE Final Report

RICHARD DAVIS, MILES JUQUETTE, REBECCA FREDRICK, DANIEL SCHUMACHER, SCHAEFFER SOMERS, STANLEY STAFIRA, JAMES WILLIAMS, and MARK ZELINKA May 1988 193 p

(Contract NGT-21-002-080)  
(NASA-CR-184698; NAS 1.26:184698; REPT-3) Avail: NTIS HC A09/MF A01 CSCL 22B

The Orbital Transfer Vehicle (OTV) and systems were researched in the following areas: avionics, crew systems, electrical power systems, environmental control/life support systems, navigation and orbital maneuvers, propulsion systems, reaction control systems (RCS), servicing systems, and structures. B.G.

**N89-20178\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

### EXPENDABLE LAUNCH VEHICLE TRANSPORTATION FOR THE SPACE STATION

ROBERT R. CORBAN Oct. 1988 13 p Presented at the 39th Congress of the International Astronautical Federation, Bangalore, India, 8-15 Oct. 1988 Previously announced in IAA as A89-17720

(NASA-TM-101947; E-4636; NAS 1.15:101947) Avail: NTIS HC A03/MF A01 CSCL 22B

Logistics transportation will be a critical element in determining the Space Station Freedom's level of productivity and possible evolutionary options. The current program utilizes the Space Shuttle as the only logistics support vehicle. Augmentation of the total transportation capability by expendable launch vehicles (ELVs) may be required to meet demanding requirements and provide for enhanced manifest flexibility. The total operational concept from ground operations to final return of support hardware or its disposal is required to determine the ELV's benefits and impacts to the Space Station Freedom program. The characteristics of potential medium and large class ELVs planned to be available in the mid-1990's (both U.S. and international partners' vehicles) indicate a significant range of possible transportation systems with varying degrees of operational support capabilities. The options available for development of a support infrastructure in terms of launch vehicles, logistics carriers, transfer vehicles, and return systems is discussed. Author

**N89-20182\*** Martin Marietta Aerospace, Denver, CO. Astronautics Group.

### SUPERFLUID HELIUM TANKER (SFHT) STUDY Final Report

RALPH N. EBERHARDT, SAM M. DOMINICK, JOHN E. ANDERSON, JOHN P. GILLE, TIM A. MARTIN, JOHN S. MARINO, HOWARD L. PAYNTER, R. ERIC TRAILL, ALFRED HERZL, SAM GOTTLIB et al. Sep. 1988 187 p

(Contract NASA-17854)  
(NASA-CR-172110; NAS 1.26:172110; MCR-88-1402) Avail: NTIS HC A09/MF A01 CSCL 22B

Replenishment of superfluid helium (SFH<sub>2</sub>) offers the potential of extending the on-orbit life of observatories, satellite instruments, sensors and laboratories which operate in the 2 K temperature regime. A reference set of resupply customers was identified as representing realistic helium servicing requirements and interfaces for the first 10 years of superfluid helium tanker (SFHT) operations. These included the Space Infrared Telescope Facility (SIRTF), the Advanced X-ray Astrophysics Facility (AXAF), the Particle Astrophysics Magnet Facility (Astromag), and the Microgravity and Materials Processing Sciences Facility (MMPS)/Critical Point Phenomena Facility (CPPF). A mixed-fleet approach to SFHT utilization was considered. The tanker permits servicing from the Shuttle cargo bay, in situ when attached to the OMV and carried to the user spacecraft, and as a depot at the Space Station. A SFHT Dewar ground servicing concept was developed which uses a dedicated ground cooling heat exchanger to convert all the liquid, after initial fill as normal fluid, to superfluid for launch. This concept permits the tanker to be filled to a near full condition, and then cooled without any loss of fluid. The final load condition can be saturated superfluid with any desired ullage volume, or the tank can be totally filled and pressurized. The SFHT Dewar and helium plumbing system design has sufficient component redundancy to meet fail-operational, fail-safe requirements, and is designed structurally to meet a 50 mission life usage requirement. Technology development recommendations were made for the selected SFHT concept, and a Program Plan and cost estimate prepared for a phase C/D program spanning 72 months from initiation through first launch in 1997. Author

**N89-20183\*** Auburn Univ., AL. VEHICLE FOR SPACE TRANSFER AND RECOVERY (VSTAR), VOLUME 1 Final Report

Jun. 1988 101 p  
(Contract NGT-21-002-080)

(NASA-CR-184827; NAS 1.26:184827) Avail: NTIS HC A06/MF A01 CSCL 22B

The Vehicle Space Transfer and Recovery (VSTAR) system is designed as a manned orbital transfer vehicle (MOTV) with the primary mission of Satellite Launch and Repair (SLR). VSTAR will provide for economic use of high altitude spaceflight for both the public and private sector. VSTAR components will be built and tested using earth based facilities. These components will then be launched using the space shuttle, into low earth orbit (LEO) where it will be constructed on a U.S. built space station. Once in LEO the vehicle components will be assembled in modules which can then be arranged in various configurations to perform the required missions. Author

**N89-20192\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

#### ADVANCED TECHNOLOGY FOR FUTURE SPACE PROPULSION SYSTEMS

LARRY A. DIEHL. Mar. 1989. 24 p. Presented at a Symposium on Space Commercialization: Roles of Developing Countries, Nashville, TN, 5-10 Mar. 1989; sponsored in part by Tennessee Univ. Space Inst.; AIAA and IAA (NASA-TM-101951; E-4846; NAS 1.15:101951) Avail: NTIS HC A03/MF A01 CSCL 21/8

The NASA Project Pathfinder contains programs to provide technologies for future transfer vehicles including those powered by both advanced chemical and electric propulsion rockets. This paper discusses the Chemical Transfer Propulsion and Cargo Vehicle Propulsion elements of Pathfinder. The program requirements and goals for both elements are discussed, and technical activities which are planned or underway are summarized. Recent progress in programs which support or proceed the Pathfinder activities is detailed. In particular, the NASA Program for Advanced Orbital Transfer Vehicle Propulsion, which acted as the precursor for the Chemical Transfer Propulsion element of Pathfinder is summarized. Author

**N89-20420\*** National Aerospace Lab., Amsterdam (Netherlands). Informatics Div.

#### A NUMERICAL METHOD FOR THE SIMULATION OF LIQUID-SOLID BODY DYNAMICS

M. E. S. VOGELS. 1 Jan. 1988. 13 p. Presented at the 12th IMACS World Congress on Scientific Computation, Paris, France, 18-22 Jul. 1988 (Contract NVR-02306N) (NLR-MP-87030-U; ETN-89-94033) Avail: NTIS HC A03/MF A01

A numerical method for the simulation of the motion of a solid body with a cavity partially filled with liquid is presented. The coupled problem is partitioned into two subproblems, the motion of the solid body and the motion of the liquid in the cavity. The two subproblems can be integrated using different time steps. The method is applied to the free, unconstrained, motion of a narrow annular tank partially filled with an inviscid liquid. In the test cases the liquid mass constitutes 10 pct, 50 pct, and 90 pct of the total mass respectively. Results suggest that the fundamental frequency increases with increasing liquid mass fraction. ESA

**N89-22637\*** Office of Technology Assessment, Washington, DC.

#### LAUNCH OPTIONS FOR THE FUTURE: SPECIAL REPORT

Jul. 1988. 110 p. (PB89-114268; OTA-ISC-383; LC-88-600540) Avail: NTIS HC A06/MF A01; also available SDO HC \$5.00 as 052-003-01117-4 CSCL 22/2

The range of launch systems that exist now or could be available before 2010 are described and the costs of meeting different demand levels are explored for launching humans and spacecraft to orbit. Also discussed is the importance of developing advanced technologies for space transportation. Author

**N89-23521\*** Rockwell International Corp., Canoga Park, CA. Rocketdyne Div.

#### SPACE STATION PROPULSION TEST BED

G. L. BRILEY and S. A. EVANS. Jan. 1989. 270 p. (Contract NAS8-35418) (NASA-CR-183615; NAS 1.26:183615; RI/RD89-104) Avail: NTIS HC A12/MF A02 CSCL 21/8

A test bed was fabricated to demonstrate hydrogen/oxygen propulsion technology readiness for the initial operating configuration (IOC) space station application. The test bed propulsion module and computer control system were delivered in December 1985, but activation was delayed until mid-1986 while the propulsion system baseline for the station was reexamined. A new baseline was selected with hydrogen/oxygen thruster modules supplied with gas produced by electrolysis of waste water from the space shuttle and space station. As a result, an electrolysis module was designed, fabricated, and added to the test bed to provide an end-to-end simulation of the baseline system. Subsequent testing of the test bed propulsion and electrolysis modules provided an end-to-end demonstration of the complete space station propulsion system, including thruster hot firings using the oxygen and hydrogen generated from electrolysis of water. Complete autonomous control and operation of all test bed components by the microprocessor control system designed and delivered during the program was demonstrated. The technical readiness of the system is now firmly established. Author

**N89-23527\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

#### RESULTS FROM BASELINE TESTS OF THE SPRE 1 AND COMPARISON WITH CODE MODEL PREDICTIONS

JAMES E. CAIRELLI, STEVEN M. GENG, and ROBERT C. SKUPINSKI (Sverdrup Technology, Inc., Cleveland, OH.) 1989. 14 p. Prepared for presentation at the 24th Intersociety Energy Conversion Engineering Conference, Washington, DC, 8-11 Aug. 1989; sponsored in part by IEEE, AIAA, ANS, ASME, SAE, ACS and AIChE (NASA-TM-102044; E-4792; NAS 1.15:102044) Avail: NTIS HC A03/MF A01 CSCL 10/2

The space power research engine (SPRE), a free piston Stirling engine with linear alternator, is being tested at NASA-Lewis as a candidate for high capacity space power. Results are presented of baseline engine tests at design and off-design operating conditions. The test results are compared with code model prediction. Author

**N89-23845\*** Aerospatiale, Cannes (France). Space and Strategic Systems Div.

#### THE FLUIDNET DEVELOPMENT AND APPLICATION TO PRELIMINARY SIZING OF FLUID LOOP SYSTEMS

S. ANDRE, J. N. CHELOTTI, J. F. GORY, and T. LAFON (Centre National d'Etudes Spatiales, Toulouse, France) Paris, France 1988. 8 p. (REPT-862-440-102; ETN-89-94495) Avail: NTIS HC A02/MF A01

An interactive application computer program applicable to preliminary design of fluid loop networks in space thermal control systems is described. The main features are portability, easy implementation, speed, and flexibility. The current version is applied to thermal and hydraulic analysis of single phase fluid loops in steady state. For first application this program is devoted to Hermes thermal control preliminary design. ESA

**N89-24216\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

#### COMPREHENSIVE REPORT OF AEROPROPULSION, SPACE PROPULSION, SPACE POWER, AND SPACE SCIENCE APPLICATIONS OF THE LEWIS RESEARCH CENTER Annual Report, 1988

1988. 167 p. Original contains color illustrations (NASA-TM-100925; NAS 1.15:100925) Avail: NTIS HC A06/MF A01 CSCL 05/1

The research activities of the Lewis Research Center for 1988



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are summarized. The projects included are within basic and applied technical disciplines essential to aeropropulsion, space propulsion, space power, and space science/applications. These disciplines are materials science and technology, structural mechanics, life prediction, internal computational fluid mechanics, heat transfer, instruments and controls, and space electronics. A.D.

**N89-24415\*** Martin Marietta Corp., Denver, CO.  
**ORBITAL TRANSFER VEHICLE: CONCEPT DEFINITION AND SYSTEM ANALYSIS STUDY Midterm Review**  
22 Jul 1987 112 p  
(Contract NAS8-26108)  
(NASA-CR-183551; NAS 1.26:183551; MCR-87-2600) Avail:  
NTIS HC A06/MF A01 CSCL 22/2

Findings and recommendations from the second extension of the Orbital Transfer Vehicle (OTV) concept definition and system analysis study are outlined. The extension study opens the scope of potential recommendations by introducing a variety of ambitious programs, and by making the large cargo vehicle recommended by the Space Transportation Architecture Studies available at no acquisition cost to the OTV program. It is a further objective of the extension study to evaluate the sensitivity of OTV program recommendations to scenario variations such as different mission models, different launch vehicle availability, and different space station availability. Program/mission issues are addressed including safety considerations for the Air Cargo Carrier (ACC) OTV. Design issues related to the development of a near-term expendable OTV, engine configuration tradeoffs, lunar missions, and program evolution are discussed. Finally, aerostatic considerations for a manned Mars mission and high speed entries are presented. A.D.

**N89-24415\*** Lockheed Missiles and Space Co., Sunnyvale, CA.  
**SUPERFLUID HELIUM TANKER STUDY (SFHT) Program Press Report**  
9 Aug 1988 253 p  
(Contract NAS8-17853)  
(NASA-CR-172114; NAS 1.26:172114; LMSC/F223517) Avail:  
NTIS HC A16/MF A02 CSCL 22/2

The Superfluid Helium Tanker (SFHT) design is examined for minimum up front cost, a low life cycle cost, and the maximum flexibility/adaptability consistent with the above objectives. The logic flow started with the collection and analysis of user requirements. A configuration trade-off was made to determine the baseline concept for SFHT that most nearly met all of the program objectives. The next task was to develop the baseline concept for the fluid subsystem. With this accomplished the baseline tanker was designed. The commonality task was completed and the program plan and cost estimate will be completed. Author

**N89-24444\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.  
**A NUMERICAL STUDY OF CHEMICALLY REACTING FLOW IN NOZZLES**  
THOMAS J. VANOVERBEKE and JIAN-SHUEN SHUEN (Sverdrup Technology, Inc., Cleveland, OH.) 1989 21 p Presented at the 25th Joint Propulsion Conference, Monterey, CA, 10-12 Jul 1989; cosponsored by the AIAA, ASME, SAE and ASCE  
(NASA-TM-102135; E-4832; NAS 1.15:102135; AIAA-89-2793)  
Avail: NTIS HC A03/MF A01 CSCL 21/8

The space station uses small rocket motors, called thrusters, for orientation control. Because of the lack of viable design tools for small rockets, the initial thruster design was basically a very small version of a large rocket motor. Thrust measurements of the initial design were lower than predicted. To improve predictions it was decided to develop a version of the RPLUS2D reacting flow code for thruster calculations. RPLUS2D employs an implicit finite volume, lower-upper symmetric successive overrelaxation (LU-SSOR) scheme for solving the complete two-dimensional Navier-Stokes equations and species transport equations in a coupled and very efficient manner. The combustion processes

are modeled by a 9-species, 18 step finite-rate chemistry model, and the turbulence is simulated by a Baldwin-Lomax algebraic model. The code is extended to handle multiple subsonic inlet conditions where the total mass flow is governed by conditions calculated at the thruster-throat. Results are shown for a thruster design where the overall mixture ratio is hydrogen rich. A calculation of a large area ratio divergent nozzle is also presented. Author

**N89-24735\*** Naval Research Lab., Washington, DC.  
**THE EXPERIMENTS OF LIPS 3**  
J. G. SEVERNS, R. M. HOBBS, N. P. ELLIOTT, R. H. TOWSLEY, and G. F. VIRSHUP (Varian Associates, Palo Alto, CA.) In NASA, Lewis Research Center, Space Photovoltaic Research and Technology, 1988. High Efficiency, Space Environment, and Array Technology p 306-322 Apr. 1989  
Avail: NTIS HC A16/MF A03 CSCL 10/1

LIPS 3 is a member of the Living Plume Shield series of spacecraft. In each LIPS project, the plume shield, a simple sheet metal cone, was structurally stiffened, and an active satellite was then built around it. The original purpose of the plume shield was to prevent the plume from solid propellant engines, which are fired outside the atmosphere after the aerodynamic shroud is jettisoned, from reaching the primary payload. The surface of LIPS 3 facing the plume also functioned in this manner, but the anterior surfaces were unaffected, and it was there that all solar arrays, sensors, and experiments were mounted. The purpose of LIPS 3 was to provide a test bed for new space power sources. With the long delays projected for schedules of the STS and other major launch systems, it appeared that a decade might pass before long term flight data could be obtained on many new and innovative power sources. The fact that a launch scheduled for early in 1987 required a plume shield was seen as a unique opportunity to obtain some of this data in a timely manner. The LIPS 3 system, the experiments placed aboard, and the experiment data acquisition subsystem are described. Various problems were encountered during integration and after launch; those which appear to effect the accuracy of experimental results are discussed. A preliminary description is given of the accuracy of the flight experiment data. Author

**N89-24838\*** National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, AL.  
**ORBITAL MANEUVERING VEHICLE (OMV) REMOTE SERVICING KIT Abstract Only**  
NORMAN S. BROWN In Tactical Weapons Guidance and Control Information Conference on Space and Military Applications of Automation and Robotics p 39 Jun. 1988  
Avail: NTIS HC A05/MF A01 CSCL 22/2

With the design and development of the Orbital Maneuvering Vehicle (OMV) progressing toward an early 1990 initial operating capability (IOC), a new era in remote space operations will evolve. The logical progression to OMV front end kits would make available in situ satellite servicing, repair, and consumables resupply to the satellite community. Several conceptual design study efforts are defining representative kits (propellant tanks, debris recovery, module servicers); additional focus must also be placed on an efficient combination module servicer and consumables resupply kit. A remote servicer kit of this type would be designed to perform many of the early maintenance/resupply tasks in both nominal and high inclination orbits. The kit would have the capability to exchange Orbital Replacement Units (ORUs), exchange propellant tanks, and/or connect fluid transfer umbilicals. Necessary transportation system functions/support could be provided by interfaces with the OMV, Shuttle (STS), or Expendable Launch Vehicle (ELV). Specific remote servicer kit designs, as well as ground and flight demonstrations of servicer technology are necessary to prepare for the potential overwhelming need. Ground test plans should adhere to the component/system/breadboard test philosophy to assure maximum capability of one-g testing. The flight demonstration(s) would most likely be a short duration, Shuttle-bay experiment to validate servicer components requiring a micro-g environment. Author

**N89-25283\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**PERFORMANCE CHARACTERIZATION AND TRANSIENT INVESTIGATION OF MULTIPROPELLANT RESISTOJET**

EDWARD P. BRAUNSCHEIDEL Jul. 1989 21 p. Presented at the 25th Joint Propulsion Conference, Monterey, CA, 10-12 Jul. 1989; cosponsored by the AIAA, ASME, SAE, and ASCE (NASA-TM-102118; E-4897; NAS 1.15:102118; AIAA-89-2837) Avail: NTIS HC A03/MF A01 CSCL 21/8

The multipropellant resistojet thruster design initially was characterized for performance in a vacuum tank using argon, carbon dioxide, nitrogen, and hydrogen, with gas inlet pressures ranging from 13.7 to 310 kPa (2 to 45 psia) over a heat exchanger temperature range of ambient to 1200 C (2200 F). Specific impulse, the measure of performance, had values ranging from 120 to 600 seconds for argon and hydrogen respectively, with a constant heat exchanger temperature of 1200 C (2200 F). When operated under ambient conditions typical specific impulse values obtained for argon and hydrogen ranged from 55 to 290 seconds, respectively. Performance measured with several mixtures of argon and nitrogen showed no significant deviation from predictions obtained by directly weighting the argon and nitrogen individual performance results. Another aspect of the program investigating transient behavior, showed responses depended heavily on the start-up scenario used. Steady state heater temperatures were achieved in 20 to 75 minutes for argon, and in 10 to 90 minutes for hydrogen. Steady state specific impulses were achieved in 25 to 60, and 20 to 60 minutes respectively. Author

**N89-26036\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**COLD-SAT: A TECHNOLOGY SATELLITE FOR CRYOGENIC EXPERIMENTATION**

H. ARIF and E. W. KROEGER 1989 13 p. Presented at the 1989 Cryogenic Engineering Conference and International Cryogenic Materials Conference, Los Angeles, CA, 24-28 Jul. 1989; sponsored by UCLA (NASA-TM-102286; E-4953; NAS 1.15:102286) Avail: NTIS HC A03/MF A01 CSCL 22/2

NASA-Lewis (LeRC) is involved in the development and validation of analytical models which describe the fluid dynamic and thermodynamic processes associated with the storage, acquisition and transfer of subcritical cryogenic fluids in low gravity. Four concurrent studies, including one in-house at LeRC, are underway to determine the feasibility of performing model validation experiments aboard a free-flying spacecraft (S/C) called Cryogenic On-Orbit Liquid Depot-Storage, Acquisition and Transfer (COLD-SAT), using liquid hydrogen as the cryogen. The technology requirements for the experiments are described along with the initial LeRC concepts for the S/C and an experiment subsystem comprising of cryogenic tankage (a supply dewar and three receiver tanks), gas pressurization bottles (both helium and autogenous hydrogen), their associated plumbing, and instrumentation for data collection. Experiments were categorized into enabling/high priority Class 1 technologies and component/system Class 2 demonstrations. As initially envisioned by LeRC, COLD-SAT would have had a 1997 launch aboard a Delta-2 for a 6 month active lifetime in a 925 km orbit with a pseudo-inertial attitude. Author

**N89-26044\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**COLD-SAT: AN ORBITAL CRYOGENIC HYDROGEN TECHNOLOGY EXPERIMENT**

J. R. SCHUSTER, JOSEPH P. WACHTER (Ford Aerospace and Communications Corp., Palo Alto, CA.), and ALBERT G. POWERS 1989 14 p. Presented at the 40th Congress of the International Astronautical Federation, Malaga, Spain, 8-14 Oct. 1989 (NASA-TM-102303; E-4984; NAS 1.15:102303; IAF-89-057) Avail: NTIS HC A03/MF A01 CSCL 22/1

The COLD-SAT spacecraft will perform subcritical liquid hydrogen storage and transfer experiments under low-gravity conditions to provide engineering data for future space

transportation missions. Consisting of an experiment module mated to a spacecraft bus, COLD-SAT will be placed in an initial 480 km circular orbit by an Atlas I commercial launch vehicle. After deployment, the three-axis-controlled spacecraft bus will provide electric power, experiment control and data management, communications, and attitude control along with propulsive acceleration levels ranging from 10(-4) to 10(-4)g. These accelerations are an important aspect of some of the experiments, as it is desired to know the effects that low gravity levels might have on the heat and mass transfer processes involved. The experiment module will contain the three liquid hydrogen tanks, valves, pressurization equipment, and instrumentation. At launch all the hydrogen will be in the largest tank, which has helium-purged MJ and is loaded and topped off by the hydrogen tanking system used for the Centaur upper stage of the Atlas. The two smaller tanks will be utilized in orbit for performing some of the experiments. The experiments are grouped into two classes on the basis of their priority, and include six regarded as enabling technology and nine regarded as enhancing technology. Author

**N89-26178\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**MODELING OF PULSED PROPELLANT REORIENTATION**

A. E. PATAG, J. I. HOCHSTEIN (Washington Univ., Saint Louis, MO.), and D. J. CHATO Jul. 1989 19 p. Presented at the 25th Joint Propulsion Conference, Monterey, CA, 10-12 Jul. 1989; sponsored in part by AIAA, ASME, SAE, and ASCE (Contract NAG3-578) (NASA-TM-102117; AIAA-89-2727; E-4892; NAS 1.15:102117) Avail: NTIS HC A03/MF A01 CSCL 20/4

Optimization of the propellant reorientation process can provide increased payload capability and extend the service life of spacecraft. The use of pulsed propellant reorientation to optimize the reorientation process is proposed. The ECLIPSE code was validated for modeling the reorientation process and is used to study pulsed reorientation in small-scale and full-scale propellant tanks. A dimensional analysis of the process is performed and the resulting dimensionless groups are used to present and correlate the computational predictions for reorientation performance. Author

**N89-26184\*** National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, MD.

**WORKSHOP ON TWO-PHASE FLUID BEHAVIOR IN A SPACE ENVIRONMENT**

THEODORE D. SWANSON, ed., AL JUHASZ, ed., W. RUSS LONG, ed. (National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, TX.), and LAURA OTTENSTEIN, ed. 1989 45 p. Workshop held in Ocean City, MD, 13-14 Jun. 1989 (NASA-CP-3043; REPT-89B00114; NAS 1.55:3043) Avail: NTIS HC A03/MF A01 CSCL 20/4

The Workshop was successful in achieving its main objective of identifying a large number of technical issues relating to the design of two-phase systems for space applications. The principal concern expressed was the need for verified analytical tools that will allow an engineer to confidently design a system to a known degree of accuracy. New and improved materials, for such applications as thermal storage and as heat transfer fluids, were also identified as major needs. In addition to these research efforts, a number of specific hardware needs were identified which will require development. These include heat pumps, low weight radiators, advanced heat pipes, stability enhancement devices, high heat flux evaporators, and liquid/vapor separators. Also identified was the need for a centralized source of reliable, up-to-date information on two-phase flow in a space environment. Author

**N89-26878\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**NASA'S CHEMICAL TRANSFER PROPULSION PROGRAM FOR PATHFINDER**

NED P. HANNUM, FRANK D. BERKOPEC, and ROBERT L. ZURAWSKI 1989 18 p. Presented at the 25th Joint Propulsion

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Conference, Monterey, CA, 10-12 Jul. 1989; cosponsored by the AIAA, ASME, SAE, and ASCE  
(NASA-TM-102298; E-4876; NAS 1.15:102298; AIAA-89-2298)  
Avail: NTIS HC A03/MF A01 CSCL 22/2

Pathfinder is a research and technology project, with specific deliverables, initiated by the National Aeronautics and Space Administration (NASA) which will strengthen the technology base of the United States civil space program in preparation for future space exploration missions. Pathfinder begins in Fiscal Year 1989, and is to advance a collection of critical technologies for these missions and ensure technology readiness for future national decisions regarding exploration of the solar system. The four major thrusts of Pathfinder are: surface exploration, in-space operations, humans-in-space, and space transfer. The space transfer thrust will provide the critical technologies needed for transportation to, and return from, the Moon, Mars, and other planets in the solar system, as well as for reliable and cost-effective Earth-orbit operations. A key element of this thrust is the Chemical Transfer Propulsion program which will provide the propulsion technology for high performance, liquid oxygen/liquid hydrogen expander cycle engines which may be operated and maintained in space. Described here are the program overview including the goals and objectives, management, technical plan, and technology transfer for the Chemical Transfer Propulsion element of Pathfinder. Author

**N89-26891#** Messerschmitt-Bölkow-Blohm G.m.b.H., Ottobrunn (Germany, F.R.). Space Communications and Propulsion Systems Div.

### MODELING OF LIQUID SLOSHING EFFECTS IN MULTI BODY SYSTEMS

K. EBERT 1988 7 p  
(MBB-UK-0024/88-PUB; ETN-89-94818) Avail: NTIS HC A03/MF A01

Two modeling methods for the sloshing dynamics of liquids in partially filled tanks in a spinning spacecraft, the homogeneous vortex flow approximation and the boundary layer model, are presented. A modeling method used to implement liquid sloshing effects into the simulation program DISCOS for multibody systems is described. The computer programs for the analysis of sloshing effects and the extended simulation program DISCOSL were applied to the INTELSAT 6 spacecraft. ESA

**N89-26895#** National Aeronautics and Space Administration, Washington, DC.

### THE NASA LOW THRUST PROPULSION PROGRAM

JAMES R. STONE and GARY L. BENNETT Jul. 1988 31 p  
Presented at the 25th Joint Propulsion Conference, Monterey, CA, 10-12 Jul. 1989; sponsored in part by AIAA, ASME, SAE, and ASCE  
(NASA-TM-102065; E-4822; NAS 1.15:102065; AIAA-89-2482)  
Avail: NTIS HC A03/MF A01 CSCL 10/2

The NASA OAST Propulsion, Power, and Energy Division supports a low thrust propulsion program aimed at providing high performance options for a broad range of near-term and far-term mission and vehicles. Low thrust propulsion has a major impact on the mission performance of essentially all spacecraft and vehicles. On-orbit lifetimes, payloads, and trip times are significantly impacted by low thrust propulsion performance and integration features for Earth-to-orbit (ETO) vehicles, Earth-orbit and planetary spacecraft, and large platforms in Earth orbit. Major emphases are on low thrust chemical propulsion, both storable and hydrogen/oxygen; low-power (auxiliary) electric arcs and resistojets; and high-power (primary) electric propulsion, including ion, magnetoplasmadynamic (MPD), and electrodeless concepts. The major recent accomplishments of the program are presented and their impacts discussed. Author

**N89-26894#** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

### DEVELOPMENT OF A HIGH POWER MICROWAVE THRUSTER, WITH A MAGNETIC NOZZLE, FOR SPACE APPLICATIONS

JOHN L. POWER and RANDALL A. CHAPMAN 1989 26 p

Presented at the 24th Microwave Power Symposium, Stanford, CT, 21-23 Aug. 1989; sponsored by the International Microwave Power Inst.

(NASA-TM-102321; E-5017; NAS 1.15:102321) Avail: NTIS HC A03/MF A01 CSCL 21/8

This paper describes the current development of a high-power microwave electrothermal thruster (MET) concept at the NASA Lewis Research Center. Such a thruster would be employed in space for applications such as orbit raising, orbit maneuvering, station change, and possibly trans-lunar or trans-planetary propulsion of spacecraft. The MET concept employs low frequency continuous wave (CW) microwave power to create and continuously pump energy into a flowing propellant gas at relative high pressure via a plasma discharge. The propellant is heated to very high bulk temperatures while passing through the plasma discharge region and then is expanded through a throat-nozzle assembly to produce thrust, as in a conventional rocket engine. Apparatus, which is described, is being assembled at NASA Lewis to test the MET concept to CW power levels of 30 kW at a frequency of 915 MHz. The microwave energy is applied in a resonant cavity applicator and is absorbed by a plasma discharge in the flowing propellant. The ignited plasma acts as a lossy load, and with optimal tuning, energy absorption efficiencies over 95 percent (based on the applied microwave power) are expected. Nitrogen, helium, and hydrogen will be tested as propellants in the MET, at discharge chamber pressures to 10 atm. Author

**N89-27455#** California Univ., Berkeley. Lawrence Berkeley Lab. Engineering Div.

### CRYOGENIC TECHNIQUES FOR LARGE SUPERCONDUCTING MAGNETS IN SPACE

MICHAEL A. GREEN Dec. 1988 26 p Presented at the Space Cryogenics Workshop, Frascati, Italy, 18 Jul. 1988

(Contract DE-AC03-78SF-00098)  
(DE89-013431; LBL-25735; CONF-8807123-2) Avail: NTIS HC A03/MF A01

A large superconducting magnet is proposed for use in a particle astrophysics experiment, ASTROMAG, which is to be mounted on the United States Space Station. This experiment will have a two-coil superconducting magnet with coils which are 1.3 to 1.7 meters in diameter. The two-coil magnet will have zero net magnetic dipole moment. The field 15 meters from the magnet will approach earth's field in low earth orbit. The issue of high Tc superconductor will be discussed in the paper. The reasons for using conventional niobium-titanium superconductor cooled with superfluid helium will be presented. Since the purpose of the magnet is to do particle astrophysics, the superconducting coils must be located close to the charged particle detectors. The trade off between the particle physics possible and the cryogenic insulation around the coils is discussed. As a result, the ASTROMAG magnet coils will be operated outside of the superfluid helium storage tank. The fountain effect pumping system which will be used to cool the coil is described in the report. Two methods for extending the operating life of the superfluid helium dewar are discussed. These include: operation with a third shield cooled to 90 K with a sterling cycle cryocooler, and a hybrid cryogenic system where there are three hydrogen-cooled shields and cryostat support heat intercept points. DOE

**N89-27708#** European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Technical Directorate.

### THE ESA POLICY AND PROGRAM FOR THE DEVELOPMENT OF ELECTRIC PROPULSION

W. RERRY, C. BARTOLI, and A. TRIPPI In DGLR, DGLR/AIAA/JSASS 20th International Electric Propulsion Conference: Proceedings p 5-16 1988

Avail: NTIS HC A03/MF E03

The benefits offered by electric propulsion are analyzed for the four applications of interest to ESA: north-south stationkeeping of geostationary satellites; orbit maneuvering and maintenance of large low-orbiting spacecraft (like the Columbus Man-Tended Free Flyer); primary propulsion for interplanetary missions, and fine



pointing, attitude and orbit control of scientific satellites. Developments in electric propulsion include: testing of a multipropellant resistojet for a manned space station; testing of a 15 kW arcjet for orbit maneuvers and maintenance of low orbiting spacecraft; final preparation of the RITA ion engine experiment on the EURECA carrier; preliminary studies of a pre-operational ion propulsion system to be flown on the Agency's SAT-2 satellite in 1992; preparation of a European primary ion propulsion system for interplanetary missions; and further development of the Field Emission Electric Propulsion system for fine attitude and orbit control of scientific spacecraft. ESA

**N89-27714#** Pisa Univ. (Italy). Dipartimento di Ingegneria Aerospaziale.

#### **ELECTRIC PROPULSION FOR LOW EARTH ORBIT APPLICATIONS**

M. ANDRENUCCI and A. TRIPPI (European Space Agency, European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) In DGLR, DGLR/AIAA/JSASS 20th International Electric Propulsion Conference: Proceedings p 62-68 1988

Avail: NTIS HC A89/MF E03

Opportunities for the application of electric propulsion systems arising from the anticipated expansion of low-Earth-orbit activities are reviewed. Inherent characteristics and performance capability of electric propulsion systems are assessed. It is shown that the various thruster concepts should not be regarded as alternative options to be traded off, but rather as a set of answers to future propulsion needs, complementary in nature and graduated in time. Potential applications related to near-Earth activities include orbit maintenance and drag cancellation (representing the most important application in low Earth orbit); and orbit raising to polar orbit and back. A specific example is discussed concerning a man-tended-free-flyer type microgravity laboratory. This example encompasses several propulsion aspects which are common to a variety of near-Earth missions and can provide insight into the applications of different electric propulsion systems in low Earth orbit. ESA

**N89-27787#** Southampton Univ. (England).

#### **THE USE OF ELECTRIC PROPULSION TECHNIQUES FOR LEO ATOMIC OXYGEN SIMULATION**

M. A. KINNERSLEY and J. P. W. STARK In DGLR, DGLR/AIAA/JSASS 20th International Electric Propulsion Conference: Proceedings p 674-680 1988 (Contract MOD-GR/E/07166)

Avail: NTIS HC A89/MF E03

Space environment simulation using electric propulsion technology is proposed. Orbiting space vehicles operating at altitudes below 1000 km are subject to impact by atmospheric species. Within the altitude range 100 to 900 km the dominant species is atomic oxygen. The velocity of the vehicle through this atmosphere results in an impact velocity of 8 km/s; the flux (altitude sensitive) is typically 10 to the 15th power atoms/sqcm/sec within the shuttle orbit. Electric propulsion techniques, yielding velocities of the same order are thus appropriate for sources attempting to simulate the LEO environment. An arc jet atomic oxygen source and its performance are discussed, particularly improving atomic oxygen flux and velocity. ESA

**N89-27789#** Texas A&M Univ., College Station. Advanced Nuclear Fuels Lab.

#### **KREM: A MODEL FOR EVALUATING ORBITAL TRANSFER VEHICLES UTILIZING NUCLEAR ELECTRIC PROPULSION SYSTEMS**

W. F. LYON In DGLR, DGLR/AIAA/JSASS 20th International Electric Propulsion Conference: Proceedings p 687-692 1/88

Avail: NTIS HC A89/MF E03

The KREM computer model was designed to evaluate performance of conceptual spacecraft designs utilizing nuclear electric propulsion systems for orbital transfer missions. The code features an interactive input environment so that the user may easily specify the parameters available for characterization of a

given mission study. Empirical models for an argon magnetoplasmadynamic (MPD) and a hydrogen arcjet thruster system are included in KREM. There are also two types of nuclear power sources represented. In addition to the thruster and power systems, the user may specify the target orbit and inclination, one-way or roundtrip transfers, the payload mass, power level, and analysis mode. The variety of analysis options available allows KREM to solve for the minimum transfer time, the optimized transfer, or analyze a variety of missions at once. In order to evaluate and demonstrate the operation of KREM, analyses of vehicle performance for a reference low Earth orbit to geosynchronous orbit mission were conducted for both the MPD and arcjet thruster systems. The MPD thruster requires less total mass to complete the reference mission throughout the entire range of operation as compared to the arcjet thruster system. However, the arcjet thruster achieves lower transfer times up to levels of 1200 sec specific impulse. ESA

**N89-28535#** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

#### **COLD-SAT: CRYOGENIC ON-ORBIT LIQUID DEPOT-STORAGE, ACQUISITION AND TRANSFER**

Jul. 1989 14 p. Original contains color illustrations (NASA-TM-102308; E-4997; NAS 1.15:102308) Avail: NTIS HC A03/MF A01 CSCL 22/1

NASA is entering an era of expanded space activity. Space-based transportation systems will carry cargo and humans from low earth orbit to geosynchronous orbit, to lunar bases, and to the Martian surface. Support of these future missions will require new, long lived, on-orbit systems using suborbital cryogenics for propellants and life support systems. Such on-orbit systems present low gravity fluid management challenges of long term storage and efficient fluid transfer and supply techniques. Development of these cryogenic systems requires on-orbit experimentation to demonstrate the capability of performing these fluid management tasks and to obtain the engineering data base required to correlate analytical tools used for system design. Author

**N89-28578#** National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, MD.

#### **SURFACE TENSION CONFINED LIQUID CRYOGEN COOLER Patent**

STEPHEN H. CASTLES, inventor (to NASA) and MICHAEL E. SCHEIN, inventor (to NASA) 18 Apr. 1989 6 p. Filed 13 Jun. 1988 Supersedes N88-29050 (26 - 23, p 3201) (NASA-CASE-GSC-13112-1; US-PATENT-4,821,807; US-PATENT-APPL-SN-205771; US-PATENT-CLASS-220-5A; US-PATENT-CLASS-220-901; US-PATENT-CLASS-62-45; US-PATENT-CLASS-62-48; US-PATENT-CLASS-208-0.7) Avail: U.S. Patent and Trademark Office CSCL 13/2

A cryogenic cooler is provided for use in craft such as launch, orbital, and space vehicles subject to substantial vibration, changes in orientation, and weightlessness. The cooler contains a small pore, large free volume, low density material to restrain a cryogen through surface tension effects during launch and zero-g operations and maintains instrumentation within the temperature range of 10 to 140 K. The cooler operation is completely passive, with no inherent vibration or power requirements.

Official Gazette of the U.S. Patent and Trademark Office

## MECHANISMS, AUTOMATION, AND ARTIFICIAL INTELLIGENCE

Includes descriptions of simulations, models, analytical techniques, and requirements for remote, automated and robotic mechanical systems.

**AB9-38180\*** National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, AL.  
**DEVELOPMENT OF AUTOMATION AND ROBOTICS FOR SPACE VIA COMPUTER GRAPHIC SIMULATION METHODS**  
 KEN FERNANDEZ (NASA, Marshall Space Flight Center, Huntsville, AL) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings, Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1147-1156. refs  
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A robot simulation system, has been developed to perform automation and robotics system design studies. The system uses a procedure-oriented solid modeling language to produce a model of the robotic mechanism. The simulator generates the kinematics, inverse kinematics, dynamics, control, and real-time graphic simulations needed to evaluate the performance of the model. Simulation examples are presented, including simulation of the Space Station and the design of telerobotics for the Orbital Maneuvering Vehicle. R.B.

**AB9-38181**  
**HOW TO REDUCE THE FLUCTUATION OF SPACE VEHICLE DURING MANIPULATOR MOVEMENT**  
 YOJI UMETANI and KAZUYA YOSHIDA (Tokyo Institute of Technology, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings, Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1223-1230. refs  
 Copyright

Space vehicle fluctuation due to reaction forces from a vehicle-mounted manipulator is discussed. A new kinematic formulation is presented which is regarded as a further theoretical contribution from the viewpoint of robotics. This formulation includes a new form of Jacobian matrix used to define the manipulability measure for space robotic arms. The relationship between the fluctuation of the base vehicle and the manipulability of the installed manipulator is analyzed, and it is proved that high manipulability indicates low fluctuation. The theoretical results are applied to problems such as arm posture definition, path planning and configuration design, and ways to reduce the fluctuation of space manipulators are discussed. Author

**AB9-38218**  
**ON THE DYNAMICS OF THE SPACE STATION BASED MOBILE SERVICING SYSTEM**  
 H. W. MAH, V. J. MODI (British Columbia, University, Vancouver, Canada), and Y. MORITA (Institute of Space and Astronautical Science, Sagami, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings, Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1343-1348.  
 (Contract NSEPC-G-1547)  
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The paper presents a relatively general formulation for studying vibrational dynamics of a flexible platform supporting a mobile base connected to a series of slewing, flexible appendages. It is applicable to missions requiring slew maneuvers of antennas, telescopes, scientific instruments, and in particular, the U.S. proposed Space Station's Mobile Remote Manipulator System (MRMS). The formulation is applied to the SCOLE configuration representing the Space Shuttle based flexible beam supporting a rigid reflector at its end. The analysis provides a useful insight

into interactions between inertia parameters, orbit geometry, translational and slewing time histories, flexibility and initial conditions. Results suggest that under critical combinations of the parameters the system may become unstable. Author

**AB9-38250**  
**ACTIVE HOLDING MECHANISM USING SHAPE MEMORY ALLOY FOR SPACE APPLICATION - SPACE ANEMONE**  
 TOSHIKI IWATA, KAZUO MACHIDA, YOSHITSUGU TODA (Ministry of International Trade and Industry, Electrotechnical Laboratory, Tsukuba, Japan), YASUO KURITA, and TOSHIO HONDA (Toshiba Corp., Kawasaki, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings, Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1641-1648.  
 Copyright

Mission efficiency in a zero-gravity environment will be improved if there is a mechanism which actively holds tools or parts in operating the manipulators. Such mechanism has been developed using two shape memory alloy wires, which are light, small, and powerful actuators. The mechanism has four fingers with three joints and is driven by tendons. The feasibility of the mechanism was investigated by a vacuum test. The real motion is compared with the ideal motion using the Lagrange equation of motion. Author

**AB9-38251**  
**A STUDY ON THE REQUIREMENTS OF THE MANIPULATOR ON THE SPACECRAFT CONSIDERING ITS ATTITUDE CONTROL**  
 MASANORI HOMMA (National Space Development Agency of Japan, Tokyo) and YASUHARU TAKASU (Mitsubishi Space Software Co., Ltd., Tokyo, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings, Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1649-1654.  
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Simulation studies of a three-link manipulator on a three-axis-stabilized spacecraft were performed, with application to such in-orbit functions as part replacement, refueling, and berthing. The actuator torque requirements have been determined for various payload masses under zero-gravity conditions. Special attention is given to the need for control systems in the orbital transfer vehicle and the accuracy of the trajectory of the manipulator in inertial space. R.R.

**AB9-38252**  
**DEVELOPMENT OF SMART MANIPULATOR FOR SPACE ACTIVITY**  
 TARO IWAMOTO, KICHIO NAKAJIMA, HIROSHI YAMAMOTO, TATSU AOKI (Hitachi, Ltd., Mechanical Engineering Research Laboratory, Tsukuba, Japan), NAOKA EZAWA (Hitachi, Ltd., Space Systems Div., Yokohama, Japan) et al. IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings, Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1655-1660. refs  
 Copyright

The Space Station and the Orbital Servicing Vehicle are planned to be launched in middle 1990s. With these facilities, various activities, such as assembly, exchange, retrieval and maintenance, will be performed in orbit. These activities, however, must be achieved in a most efficient way with the minimal work loads of the astronauts. To this end, use of improved manipulators is expected to be the solution. A class of manipulators is named that has improved performance and operability attained by the advanced control schemes, such as the TMCC (Terminal Motion Corresponding Control) Smart Manipulator. This paper describes the development of the Smart Manipulator and its current test results. Author

**AB9-38275**  
**DEVELOPMENT OF EQUIPMENT EXCHANGE UNIT FOR JAPANESE EXPERIMENT MODULE OF SPACE STATION**

GAKUMEI HATTORI (National Space Development Agency of Japan, Tokyo), HIROSHI ITOH, FUMIAKI SANO, HISAO KOJIMA, YOSHITERU YAMAMOTO (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan) et al. IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1819-1824.

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The equipment exchange unit (EEU) which is projected to be attached to the exposed facility (EF) of the Space Station JEM is described. The EEU will provide a simple means for the automatic exchange of experimental payloads, accommodate up to 10 payloads, and reduce crew experiment time and EVA time. Tests have validated such aspects of the EEU functional requirements as the ability to connect and disconnect in a rapid single operation all of the utility interfaces (power and fluids) between the EF and the payloads. R.H.

**A89-38276**

#### REMOTE MANIPULATOR SYSTEM OF JAPANESE EXPERIMENT MODULE

KOJI YAMAWAKI, KESATOSHI KURAOKA (National Space Development Agency of Japan, Tokyo), TAMUJIRO SUMI, RYO OKAMURA, and JUNICHI KATO (Toshiba Corp., Kawasaki, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1825-1829. refs

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This paper presents an overview of the current development status of the remote manipulator system of the Japanese Experiment Module (JEM). The manipulator system is mainly characterized by a combination of a 10-m main arm and a 2-m small arm that can be attached on orbit to the main arm and used for tasks requiring dexterity. While basic control of the main arm is executed automatically, the small arm is principally teleoperated by a master-slave bilateral control system. Visual information to the operator is provided by TV system beside a window of the pressurized JEM module. Author

**A89-38383**

#### HARDWARE SIMULATION OF RETRIEVING A TARGET BY SPACE MANIPULATOR IN 0-GRAVITY ENVIRONMENT

SHUICHIRO FUKUZAWA IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 2571-2575.

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The design and simulation testing of an autonomous-type 4-DOF space manipulator system for use on free-flying platforms are reported. The system comprises a CCD camera as optical sensor, a target, a robot arm with four rotational DOFs, and a 16-bit microcomputer. The basic equations of motion and the control law are outlined; various techniques for simulating zero-gravity conditions on the ground are discussed; and results obtained using a gimbal method are summarized. The validity of the simulation and the asymptotic stability of the closed-loop control law are demonstrated, and it is shown that the translational and rotational DOFs of the spacecraft should be completely separated. T.K.

**A89-40811#**

#### A FORMULATION FOR STUDYING DYNAMICS OF THE SPACE STATION BASED MRMS AND ITS APPLICATION

YASUHIRO MORITA and VINOD J. MODI (British Columbia, University, Vancouver, Canada) Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 37, no. 422, 1989, p. 128-134. In Japanese, with abstract in English. refs

A relatively general formulation for studying dynamics of a flexible Mobile Remote Manipulator System (MRMS), supported by an orbiting flexible platform, is developed using the Lagrangian approach with generalized forces accounting for the environmental effects, damping, and control. The computational algorithm is so structured as to isolate the effects of various system parameters,

thus helping in assessment of their relative importance. Application of the general formulation, illustrated through several typical MRMS configurations of practical importance, reveals complex interactions between vibrational and librational degrees of freedom, in the presence of MRMS maneuver, over a range of system parameters and initial conditions. Effectiveness of the formulation is also demonstrated through another illustrative example of the SCOLE configuration representing the Shuttle-based flexible beam supporting a rigid reflector plate at its end. Author

**A89-41457**

#### SPACE ROBOTICS - INTRA-VEHICULAR OPERATIONS

BARRY KEEPENCE (Marconi Computer Systems, Ltd., Bristol, England) British Interplanetary Society, Journal (ISSN 0007-084X), vol. 42, May 1989, p. 239-246. refs

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The introduction of robotics in space will have a major impact on payload, spacecraft, and ground station design and operations. An intelligent and advanced robot could perform many tasks as well as or even better than astronauts. The possible applications of robots in Space are manifold but, in the near future, first applications are likely to be intra-vehicular. This paper analyses and considers payload requirements in the context of robotic operations. The specific requirements and constraints of a robot operating in space are examined. The problems of teleoperation, teleprogramming and the implications of integrating robotics into telepresence operations are discussed. Author

**A89-43141**

#### TELEROBOTICS SYSTEM SIMULATION FOR SPACE APPLICATIONS

SHOU X ZHANG (Northwestern Polytechnical University, Xian, People's Republic of China), FAN T. TSENG, and BERNARD J. SCHROER (Alabama, University, Huntsville) IN: 1988 Annual Summer Computer Simulation Conference, 20th, Seattle, WA, July 25-28, 1988, Proceedings. San Diego, CA, Society for Computer Simulation International, 1988, p. 713-718. Research supported by Alabama Research Institute and Alabama Dept. of Economic and Community Affairs. refs

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The development of a telerobotics laboratory for studying man's role in space telerobotics is discussed. The laboratory is configured around a Puma 562 6 DOF arm. A high-resolution black and white CCD camera is mounted on the arm. The following basic tasks were identified for space servicing, structure assembling, and contingencies: (1) the operation of mechanical connections, electrical connections, and latching devices, (2) the grasping and positioning of objects, and (3) the operation of cutting and welding devices. K.K.

**A89-43719\*** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

#### AUTOMATION AND ROBOTICS FOR THE SPACE STATION - AN ATAC PERSPECTIVE

ROBERT R. NUNAMAKER (NASA, Langley Research Center, Hampton, VA) IN: Space - A new community of opportunity; Proceedings of the Thirty-fourth Annual AAS International Conference, Houston, TX, Nov. 3-5, 1987. San Diego, CA, Univelt, Inc., 1989, p. 343-348.

(AAS PAPER 87-666) Copyright

The study of automation and robotics for the Space Station by the Advanced Technology Advisory Committee is surveyed. The formation of the committee and the methodology for the Space Station automation study are discussed. The committee's recommendations for automation and robotics research and development are listed. R.B.

**A89-45777\*** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

#### TELEROBOTICS DESIGN ISSUES FOR SPACE CONSTRUCTION

JEFFREY H. SMITH, MAX GYAMFI, KENT VOLKMER, and WAYNE ZIMMERMAN (California Institute of Technology, Jet Propulsion



## 10 MECHANISMS, AUTOMATION, AND ARTIFICIAL INTELLIGENCE

Laboratory, Pasadena) *IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 644-655. refs*  
(Contract NAS7-918)  
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The use of a Flight Telerobotic Servicer (FTS) in the construction of the Space Station is examined. A methodology is presented for evaluating possible construction tasks, telerobotic performance capabilities, development costs, and operational constraints. The use of telerobotics as a substitute for human EVA activities and the construction tasks which an FTS could perform in the next 8-10 years are considered. The cost-effectiveness of construction using the FTS is compared with that of construction using the STS. The trade-offs associated with using the FTS are discussed in detail.  
R.B.

**A89-45778\*** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

### ROBOTIC SPACE CONSTRUCTION

RANDOLPH W. MIXON, WALTER W. HANKINS, III (NASA, Langley Research Center, Hampton, VA), and MARION A. WISE (Wise Technical Services, Hampton, VA) *IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 656-669. refs*  
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Research at Langley AFB concerning automated space assembly is reviewed, including a Space Shuttle experiment to test astronaut ability to assemble a repetitive truss structure, testing the use of teleoperated manipulators to construct the Assembly Concept for Construction of Erectable Space Structures I truss, and assessment of the basic characteristics of manipulator assembly operations. Other research topics include the simultaneous coordinated control of dual-arm manipulators and the automated assembly of candidate Space Station trusses. Consideration is given to the construction of an Automated Space Assembly Laboratory to study and develop the algorithms, procedures, special purpose hardware, and processes needed for automated truss assembly.  
R.B.

**A89-45780**

### ROBOTICS RESEARCH FOR CONSTRUCTION IN SPACE

IRVING J. OPPENHEIM (Carnegie-Mellon University, Pittsburgh, PA) *IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 679-690. Research sponsored by the U.S. Bureau of Mines, DOE, Electric Power Research Institute, and NSF. refs*  
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Research in construction robotics, terrestrial or otherwise, has focused on issues which are broadly pertinent to space applications. Construction robotics is distinguished by a demand for cognitive capabilities because of the unstructured domain and the additional necessity to generate task plans on the basis of information from the force domain and the spatial domain. Substantial progress has been made on six separate research programs, all conducted in the contexts of civil engineering, architecture, or construction: inertia effects in manipulation, control of flexible manipulators, force cognitive manipulation, domain modelling, spatial reasoning, and domain specific task planning. For each program the challenge is described, the results summarized, and the pertinence to space applications stated.  
Author

**A89-45781\*** Lockheed Engineering and Management Services Co., Inc., Houston, TX.

### ROBOTIC INFLUENCE IN THE CONCEPTUAL DESIGN OF MECHANICAL SYSTEMS IN SPACE AND VICE VERSA - A SURVEY

GEORGE F. SANGER (Lockheed Engineering and Management Services Co., Inc., Houston, TX) *IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society*

*of Civil Engineers, 1988, p. 691-701.*

(Contract NAS9-17900)

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A survey of methods using robotic devices to construct structural elements in space is presented. Two approaches to robotic construction are considered: one in which the structural elements are designed using conventional aerospace techniques which tend to constrain the function aspects of robotics and one in which the structural elements are designed from the conceptual stage with built-in robotic features. Examples are presented of structural building concepts using robotics, including the construction of the SP-100 nuclear reactor power system, a multimirror large aperture IR space telescope concept, retrieval and repair in space, and the Flight Telerobotic Servicer.  
R.B.

**A89-45782\*** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

### SIMULATOR FOR TELEROBOTIC ASSEMBLY, MAINTENANCE AND REPAIR OF LARGE SPACE STRUCTURES

MLADEN LUKSIC (California Institute of Technology, Jet Propulsion Laboratory, Pasadena; Digital Equipment Corp., Colorado Springs, CO) *IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 702-711. refs*  
Copyright

A first approximation level computer simulator for telerobotic assembly of large space structures is described. Approach, methodology and initial results are presented. An example based on simulation of automated assembly of basic structure for the Space Station is discussed.  
Author

**A89-45790**

### THE ROLE OF A MOBILE TRANSPORTER IN LARGE SPACE STRUCTURES ASSEMBLY AND MAINTENANCE

R. W. ADKISSON (McDonnell Douglas Astronautics Co., Space Station Div., Huntington Beach, CA) *IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 787-796.*  
Copyright

The phased Space Station Mobile Transporter (MT) is examined as a representative support vehicle for large space structures. The functional and interface design requirements are summarized, and the MT system is described, listing values for the most important MT capabilities. The MT operations with respect to the assembly work platform, Space Station assembly, and Space Station service and maintenance are addressed. Alternate applications of the MT system or subsystems as an autonomous transporter, to space travel vehicle support, and to lunar bases are discussed.  
C.D.

**A89-51707#**

### ISSUES IN THE DYNAMICS AND CONTROL OF FLEXIBLE ROBOT MANIPULATORS

H. BARUH and S. S. K. TADIKONDA (Rutgers University, New Brunswick, NJ) *(Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987 p. 529-547) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Sept.-Oct. 1989, p. 659-671. Previously cited in issue 02, p. 204, Accession no. A89-11683. refs*  
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**A89-52647#** Case Western Reserve Univ., Cleveland, OH.

### NEW RESULTS CONCERNING THE USE OF KINEMATICALLY REDUNDANT MANIPULATORS IN MICROGRAVITY ENVIRONMENTS

R. D. QUINN and N. J. LIN (Case Western Reserve University, Cleveland, OH) *IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and*

Astronautics, 1989, p. 1150-1157. refs  
(Contract NAG3-761)  
(AIAA PAPER 89-3562) Copyright

This paper is concerned with the development of control strategies for kinematically redundant manipulators to be used in Space Station laboratories. These robots must be able to conduct experiments and manufacturing processes without disturbing the microgravity environment, and thus their dynamic base reactions/motions must be nearly eliminated. Redundant degrees of freedom permit the inverse kinematics problem to be solved in conjunction with the minimization of a cost function defined as a weighted sum of the base reactions. It is shown that the weights in the cost function should be used as an additional set of parameters in the minimization problem. The actual performance of the local optimal trajectory approach is demonstrated to be not as good as was previously reported. Author

**A89-52710#**

#### CONTROL OF A TWO-LINK FLEXIBLE MANIPULATOR

J. Z. SASIADEK and K. MIN (Carleton University, Ottawa, Canada) IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1698-1704. refs  
(AIAA PAPER 89-3563) Copyright

This paper presents dynamics and a control system for a two-link flexible manipulator. Dynamics of the manipulator has been simulated using finite elements methods. Several modes of vibration have been taken into account and the result for first three modes have been used for the position/vibration control. Author

**A89-53436**

#### NONHOLONOMIC PATH PLANNING OF SPACE ROBOTS

YOSHIHIKO NAKAMURA and RANJAN MUKHERJEE (California, University, Santa Barbara) IN: 1989 IEEE International Conference on Robotics and Automation, Scottsdale, AZ, May 14-19, 1989, Proceedings, Volume 2. Washington, DC, IEEE Computer Society Press, 1989, p. 1050-1055. Research supported by NSF. refs  
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The nonholonomic mechanical structure of a space robot and its path planning are discussed. The conservation of angular momentum works as a nonholonomic constraint, whereas the conservation of linear momentum is a holonomic one. In this framework a vehicle with a 6-DOF manipulator is described as a nine-variable system with six inputs. This implies the possibility of controlling the vehicle orientation as well as the joint variables of the manipulator by actuating the joint variables only if the trajectory is carefully planned, although both the variables and the trajectory cannot be controlled independently. In planning a feasible path, a system that consists of a vehicle and a 6-DOF manipulator can be treated as a 9-DOF kinematically redundant system. The nonholonomic mechanical structure of the space vehicle/manipulator system is shown, and a path planning scheme for nonholonomic systems using Lyapunov functions is proposed. I.E.

**A89-53447\*** Bolt, Beranek, and Newman, Inc., Cambridge, MA. SIMULATION-MODELING TOOL FOR EVALUATION OF SPACE TELEROBOTIC CONTROL STRATEGIES

KEVIN CORKER and MICHAEL CRAMER (BBN Systems and Technologies Corp., Cambridge, MA) IN: 1989 IEEE International Conference on Robotics and Automation, Scottsdale, AZ, May 14-19, 1989, Proceedings, Volume 3. Washington, DC, IEEE Computer Society Press, 1989, p. 1322-1326. Research sponsored by NASA. refs  
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An object-oriented software graphic simulation and modeling tool is developed to explore human/autonomous control allocation for varied operational scenarios. The system provides designers with LISP workstations through which to simulate telerobotic operations, model human performance in those operations, examine task performance profiles, and investigate control and diagnostic strategies. It is suggested that the provision of such

analytic tools along with the presentation of performance projections can assist designers in rapidly and conveniently exploring design alternatives for telerobotic system control. I.E.

**A89-53449**

#### SENSORY FEEDBACK CONTROL FOR SPACE MANIPULATORS

YASUHIRO MASUTANI, FUMIO MIYAZAKI, and SUGURU ARIMOTO (Osaka University, Toyonaka, Japan) IN: 1989 IEEE International Conference on Robotics and Automation, Scottsdale, AZ, May 14-19, 1989, Proceedings, Volume 3. Washington, DC, IEEE Computer Society Press, 1989, p. 1346-1351. refs  
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The positioning control problem of the end tips of space manipulators which have no fixed bases is investigated. According to the momentum-conservation law, the system is represented by a nonholonomic model. Thus, the conventional control method for industrial robots, based on a local feedback at each joint, is not applicable when the end tip must be positioned at a floating target. For this problem, the sensory feedback control scheme is based on the artificial potential defined in the sensor coordinate frame. The generalized Jacobian plays an important role in determining the control torque of each joint from the data of the external sensors. This scheme is simple, and the stability of the system is strictly assured. The approximate Jacobian, which needs less computation and less parameter identification, is shown to work well. I.E.

**A89-53455#**

#### SPACE ROBOTICS - AUTOMATA IN UNSTRUCTURED ENVIRONMENTS

RONALD LUMIA (NIST, Robot Systems Div., Gaithersburg, MD) IN: 1989 IEEE International Conference on Robotics and Automation, Scottsdale, AZ, May 14-19, 1989, Proceedings, Volume 3. Washington, DC, IEEE Computer Society Press, 1989, p. 1467-1471. refs

The problems associated with the development of robots for space applications are reviewed. Within the Space Station context, robots will operate in a relatively unstructured environment and must have the ability to deal with unexpected events; hence a great deal of experimentation is required to determine the best algorithms for task decomposition, world modeling, and sensory processing. The NASA/NBS Standard Reference Model for telerobot systems (NASREM), an architecture which supports the evolutionary development of the robot, is presented. NASREM forms the basis for a testbed system which allows researchers to develop, test, and evaluate different hardware and software approaches. NASREM is also used in the telerobot, so that the transition from the teleoperated mode to more autonomous modes of robot operation is gradual rather than abrupt. NASREM has been adopted by NASA for the Flight Telerobotic Servicer, a two-armed robot intended to help build and maintain the Space Station. I.E.

**A89-53458\*** Massachusetts Inst. of Tech., Cambridge.

#### A METHOD FOR ESTIMATING THE MASS PROPERTIES OF A MANIPULATOR BY MEASURING THE REACTION MOMENTS AT ITS BASE

HARRY WEST, EVANGELOS PAPADOPOULOS, STEVEN DUBOWSKY, and HANSON CHEAH (MIT, Cambridge, MA) IN: 1989 IEEE International Conference on Robotics and Automation, Scottsdale, AZ, May 14-19, 1989, Proceedings, Volume 3. Washington, DC, IEEE Computer Society Press, 1989, p. 1510-1516. Research supported by NASA, DARPA, and Oak Ridge National Laboratory. refs  
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Emulating on earth the weightlessness of a manipulator floating in space requires knowledge of the manipulator's mass properties. A method for calculating these properties by measuring the reaction forces and moments at the base of the manipulator is described. A manipulator is mounted on a 6-DOF sensor, and the reaction forces and moments at its base are measured for different positions of the links as well as for different orientations of its base. A

## 10 MECHANISMS, AUTOMATION, AND ARTIFICIAL INTELLIGENCE

procedure is developed to calculate from these measurements some combinations of the mass properties. The mass properties identified are not sufficiently complete for computed torque and other dynamic control techniques, but do allow compensation for the gravitational load on the links, and for simulation of weightless conditions on a space emulator. The algorithm has been experimentally demonstrated on a PUMA 260 and used to measure the independent combinations of the 16 mass parameters of the base and three proximal links. I.E.

**AB-53466**

### PREDICTIVE AND KNOWLEDGE-BASED TELEROBOTIC CONTROL CONCEPTS

G. HIRZINGER, J. HEINDL, and K. LANDZETTEL (DLR, Institut fuer Dynamik der Flugsysteme, Weßling, Federal Republic of Germany) IN: 1989 IEEE International Conference on Robotics and Automation, Scottsdale, AZ, May 14-19, 1989, Proceedings, Volume 3. Washington, DC, IEEE Computer Society Press, 1989, p. 1768-1777. refs

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The problems that arise when sensor-controlled robots in space are teleoperated from ground stations are discussed. A supervisory control concept is described that makes it possible to realize shared control between teleoperator and sensor-controlled robot in a variety of configurations. Predictive three-dimensional computer graphics seem to be the only way to successfully cope with the problem of transmission-time delays of several seconds. Appropriate estimation schemes in combination with knowledge-based world modeling are outlined, which include models of the delay lines, the robot, moving objects, etc., and which derive the necessary updates from sensory data as they are sent down from the spacecraft to earth (e.g., via real-time stereo vision). The space robot technology experiment Rotex scheduled for the second FRG Spacelab mission (D2) is taken as a basis for the problem description. I.E.

**AB-53831\*** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.  
**TELEROBOTIC RESEARCH FOR IN-SPACE STRUCTURAL ASSEMBLY AND SERVICING**

ALFRED J. MEINTEL, JR. (NASA, Langley Research Center, Hampton, VA) Space Artificial Intelligence Robotics/Automation Symposium, Tokyo, Japan, Oct. 16-19, 1989, Paper. 9 p. refs

The paper reviews Langley's Telerobotic Technology Program and the recent and planned research in automated space assembly. Research areas include multiple manipulator coordination and control, automatic modes, evaluation of control modalities for teleoperated tasks, active sensing for world modeling and control, and architectures for distributed telerobotic systems. Studies of master/slave teleoperators performing representative space tasks showed that current teleoperator systems can be used to accomplish remote space operations. These studies also identified that research is required to improve the systems to reduce operator workload and task completion time. Closed-loop noncontact and contact sensor based control for automatic acquisition, positioning, and active compliance have been developed. A control structure for multiple manipulator coordination and control with manual, shared, and automatic modes performing space type tasks is being evaluated. C.E.

**AB-54345**

### INTELLIGENT AVIONICS

WARREN MOSELEY (Alabama, University, Huntsville) IN: International Conference on Hypersonic Flight in the 21st Century, 1st, Grand Forks, ND, Sept. 20-23, 1988, Proceedings. Grand Forks, ND, University of North Dakota, 1988, p. 226-234. Copyright

Such next-generation aerospace systems as the Space Station, the Advanced Tactical Fighter, autonomous vehicles, and hypersonic cruise aircraft, will require real-time expert system collaboration with crews and ground controllers. In avionics applications, such AI systems would be intimately involved in mission planning on the basis of real-time-accessible guidance

and sensor data; these data can be processed by highly parallel computer architectures. The activities of the ground personnel responsible for the inspection and maintenance of these aircraft will also be greatly aided by the application of AI avionics that can be interrogated to ascertain subsystems' status. O.C.

**N89-20184\*** Auburn Univ., AL.

### VEHICLE FOR SPACE TRANSFER AND RECOVERY (VSTAR), VOLUME 2: SUBSTANTIATING ANALYSES AND DATA Final Report

Jun. 1988 63 p

(Contract NGT-21-002-080)

(NASA-CR-184828; NAS 1.26:184828) Avail: NTIS HC A04/MF A01 CSCL 22B

The Vehicle Space Transfer and Recovery (VSTAR) system is designed as a manned orbital transfer vehicle (MOTV) with the primary mission of Satellite Launch and Repair (SLR). Reference materials, calculations and trade studies used in the analysis and selection of VSTAR components. Each major VSTAR system is examined separately. Simple graphs and tables are used to make qualitative comparisons of various VSTAR component candidates. Equations and/or calculations used for a particular analysis are also included where applicable. Author

**N89-20474\*** National Aerospace Lab., Amsterdam (Netherlands), Space Div.

### TRANSLATIONAL AND ROTATIONAL DYNAMICS OF RIGID SPACECRAFT-BASED MANIPULATORS

P. TH. L. M. VANWOERKOM 5 Jan. 1987 175 p

(Contract NIVR-02506N)

(NLR-TR-87014-U; ETN-89-94062; AD-B120173L; PB89-152862)

Avail: NTIS HC A08/MF A01

The case of a spacecraft-based manipulator with rigid links is studied. Approaches to mathematical modeling are reviewed, and arguments for using the so-called Newton-Euler approach are presented. The equations obtained are manipulated to obtain a compact vector equation, suitable for analysis of inverse dynamics as well as forward dynamics. Results are compared with literature. Applications and extensions are described, and recommendations for further research on the subject are presented. ESA

**N89-20481\*** Oak Ridge National Lab., TN.

### TELEROBOTIC MANIPULATOR DEVELOPMENTS FOR GROUND-BASED SPACE RESEARCH

J. N. HERNDON, S. M. BABCOCK, P. L. BUTLER, H. M. COSTELLO, R. L. GLASSELL, REID L. KRESS, D. P. KUBAN, J. C. ROWE, D. M. WILLIAMS, and A. J. MEINTEL (National Aeronautics and Space Administration, Langley Research Center, Hampton, VA) 1988 21 p Presented at the 3rd Topical Meeting on Robotics and Remote Systems, Charleston, SC, 13-16 Mar. 1989. Sponsored by NASA

(Contract DE-AC05-84OR-21400)

(NASA-CR-184736; NAS 1.26:184736; DE89-005108;

CONF-890304-31) Avail: NTIS HC A03/MF A01 CSCL 13/9

New opportunities for the application of telerobotic systems to enhance human intelligence and dexterity in the hazardous environment of space are presented by the National Aeronautics and Space Administration (NASA) Space Station Program. Because of the need for significant increases in extravehicular activity and the potential increase in hazards associated with space programs, emphasis is being heightened on telerobotic systems research and development. The Automation Technology Branch at NASA Langley Research Center currently is sponsoring the Laboratory Telerobotic Manipulator (LTM) program at Oak Ridge National Laboratory to develop and demonstrate ground-based telerobotic manipulator system hardware for research and demonstrations aimed at future NASA applications. The LTM incorporates traction drives, modularity, redundant kinematics, and state-of-the-art hierarchical control techniques to form a basis for merging the diverse technological domains of robust, high-dexterity teleoperations and autonomous robotic operation into common hardware to further NASA's research. DOE



**N89-21824\*** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.  
**A TELEROBOTIC SYSTEM FOR AUTOMATED ASSEMBLY OF LARGE SPACE STRUCTURES**  
 MARVIN D. RHODES, RALPH W. WILL, and MARION A. WISE (PRC Kentron, Inc., Hampton, VA.) Mar. 1989 21 p  
 (NASA-TM-101518; NAS 1.15:101518) Avail: NTIS HC A03/MF A01 CSCL 22/2

Future space missions such as polar platforms and antennas are anticipated to require large truss structures as their primary support system. During the past several years considerable research has been conducted to develop hardware and construction techniques suitable for astronaut assembly of truss structures in space. A research program has recently been initiated to develop the technology and to demonstrate the potential for automated in-space assembly of large erectable structures. The initial effort will be focussed on automated assembly of a tetrahedral truss composed of 2-meter members. The facility is designed as a ground based system to permit evaluation of assembly concepts and was not designed for space qualification. The system is intended to be used as a tool from which more sophisticated procedures and operations can be developed. The facility description includes a truss structure, motionbases and a robot arm equipped with an end effector. Other considerations and requirements of the structural assembly describe computer control systems to monitor and control the operations of the assembly facility.

Author

**N89-22108\*** Teledyne Brown Engineering, Huntsville, AL. Space Program Div.  
**USER NEEDS, BENEFITS AND INTEGRATION OF ROBOTIC SYSTEMS IN A SPACE STATION LABORATORY Interim Report, Oct. 1987 - Jan. 1989**  
 K. E. FARNELL, J. A. RICHARD, E. PLOGE, M. B. BADGLEY, C. R. KONKEL, and W. R. DODD Jan. 1989 175 p  
 (Contract NAS3-25278)  
 (NASA-CR-182261; NAS 1.26:182261; TBE-SSD-P601-89-40)  
 Avail: NTIS HC A08/MF A01 CSCL 13/9

The methodology, results and conclusions of the User Needs, Benefits, and Integration Study (UNBIS) of Robotic Systems in the Space Station Microgravity and Materials Processing Facility are summarized. Study goals include the determination of user requirements for robotics within the Space Station, United States Laboratory. Three experiments were selected to determine user needs and to allow detailed investigation of microgravity requirements. A NASTRAN analysis of Space Station response to robotic disturbances, and acceleration measurement of a standard industrial robot (Intellidex Model 660) resulted in selection of two ranges of low gravity manipulation: Level 1 (10-3 to 10-5 G at greater than 1 Hz) and Level 2 (less than 10-6 G at 0.1 Hz). This included an evaluation of microstepping methods for controlling stepper motors and concluded that an industrial robot actuator can perform milli-G motion without modification. Relative merits of end-effectors and manipulators were studied in order to determine their ability to perform a range of tasks related to the three low gravity experiments. An Effectivity Rating was established for evaluating these robotic system capabilities. Preliminary interface requirements were determined such that definition of requirements for an orbital flight demonstration experiment may be established.

Author

**N89-22628\*** Joint Publications Research Service, Arlington, VA.  
**DEVELOPMENT OF ORBITAL WELDING TECHNOLOGY**  
 A. TARASOV In its JPRS Report: Science and Technology. USSR: Space p 46-49 17 Aug. 1988 Transl. into ENGLISH from Pravda (Moscow, USSR), 29 Mar. 1988 p 2  
 Copyright Avail: NTIS HC A05/MF A01

The history of Soviet orbital welding is briefly outlined, starting with the ground design up to and including the actual performance in space.

B.G.

**N89-22922\*** Oak Ridge National Lab., TN.  
**TRACTION-DRIVE FORCE TRANSMISSION FOR TELEROBOTIC JOINTS**

D. M. WILLIAMS and D. P. KUBAN 1989 15 p Presented at the NASA Conference on Space Telerobotics, Pasadena, CA, 31 Jan. 1989 Sponsored by NASA, Langley Research Center, Hampton, VA  
 (Contract DE-AC05-84OR-21400)  
 (NASA-CR-183331; NAS 1.26:183331; DE89-006687; CONF-890153-3) Avail: NTIS HC A03/MF A01 CSCL 13/9

The U.S. Space Station Program is providing many technological developments to meet the increasing demands of designing such a facility. One of the key areas of research is that of telerobotics for space station assembly and maintenance. Initial implementation will be teleoperated, but long-term plans call for autonomous robotics. One of the essential components for making this transition successful is the manipulator joint mechanism. Historically, teleoperated manipulators and industrial robotics have had very different mechanisms for force transmission. This is because the design objectives are almost mutually exclusive. A teleoperator must have very low friction and inertia to minimize operator fatigue; backlash and stiffness are of secondary concern. A robot, however, must have minimum backlash, and high stiffness for accurate and rapid positioning. A joint mechanism has yet to be developed that can optimize these divergent performance objectives. A joint mechanism that approaches this optimal performance was developed for NASA Langley, Automation Technology Branch. It is a traction-drive differential that uses variable preload mechanisms. The differential provides compact, dexterous motion range with a torque density similar to geared systems. The traction drive offers high stiffness and zero backlash—for good robotic performance, and the variable-loading mechanism (VLM) minimizes the drive-train friction—for improved teleoperation. As a result, this combination provides a mechanism to allow advanced manipulation with either teleoperated control or autonomous robotic operation. This paper will address the design principles of both of these major components of the joint mechanism.

DOE

**N89-23068\*** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.  
**THE SPACE STATION FLIGHT TELEROBOTIC SERVICER AND THE HUMAN**

KELLI F. WILLSHIRE, JAMES G. WATZIN (National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.), and PHYLLIS K. MILLEN Apr. 1989 34 p Presented at the 2nd International Conference on the Human-Computer Interaction, Honolulu, HI, 10-15 Aug. 1987  
 (NASA-TM-100615; NAS 1.15:100615) Avail: NTIS HC A03/MF A01 CSCL 05/8

The Space Station Flight Telerobotic Servicer (FTS) and its human-machine interaction issues are described. Included is a discussion of the FTS strawman concept and the FTS workstation human factor issues.

Author

**N89-23892\*** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.  
**THE 23RD AEROSPACE MECHANISMS SYMPOSIUM**  
 Washington Mar. 1989 342 p Symposium held in Huntsville, AL, 3-5 May 1989; sponsored by NASA, Washington, California Inst. of Tech., Pasadena, and LMSC, Sunnyvale, CA  
 (NASA-CP-3032; M-611; NAS 1.55:3032) Avail: NTIS HC A15/MF A02 CSCL 20/11

Technological areas covered include space lubrication, bearings, aerodynamic devices, spacecraft latches, deployment, positioning, and pointing. Devices for Space Station docking and manipulator and teleoperator mechanisms are also described.

**N89-23893\*** European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).  
**THE EVOLUTION OF SPACE MECHANISMS IN THE ESA R AND D PROGRAM**

D. WYN-ROBERTS *In NASA, Marshall Space Flight Center, The 23rd Aerospace Mechanisms Symposium p 1-16 Mar. 1989*  
 Avail: NTIS HC A15/MF A02 CSCL 13/9

The status of recently completed and already ongoing technology developments, as well as some of the most important future developments of the European Space Agency are discussed. Among the subjects considered are Scientific Satellites, Columbus space station development, applications spacecraft for communications, Earth observation and meteorology, and the Ariane V and Hermes space transportation systems. *Author*

**N89-23895\*** National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, TX.

**THE DESIGN AND ANALYSIS OF A DOUBLE SWIVEL TOGGLE RELEASE MECHANISM FOR THE ORBITER STABILIZED PAYLOAD DEPLOYMENT SYSTEM**

GUY L. KING and TED TSAI *In NASA, Marshall Space Flight Center, The 23rd Aerospace Mechanisms Symposium p 39-57 Mar. 1989*

Avail: NTIS HC A15/MF A02 CSCL 13/9

The NASA Stabilized Payload Deployment System (SPDS) is discussed. The lightweight and heavy-duty system rolls payloads over the orbiter's side rather than ejecting them upward. The system will enhance the orbiter's capability of carrying larger and heavier payloads. The design, function, and analysis of a new three-pin double swivel toggle release mechanism which is crucial to the successful deployment of the SPDS are described. *Author*

**N89-23896\*** I.A.M. Rinaldo Piaggio, Finale Ligure (Italy).  
**DESIGN AND TESTING OF A DEPLOYABLE, RETRIEVABLE BOOM FOR SPACE APPLICATIONS**

P. BECCHI and S. DELLAMICO *In NASA, Marshall Space Flight Center, The 23rd Aerospace Mechanisms Symposium p 101-112 Mar. 1989*

Avail: NTIS HC A15/MF A02 CSCL 22/2

The Deployable Retrievable Boom which was developed as a part of the joint U.S.-Italian Tethered Satellite System (TSS) is described. The design mission of the boom is to support, deploy, and retrieve an experiment package for the study of the electromagnetic field surrounding the satellite. The mechanism includes a jettisoning provision and deployable harness for the supported payloads connection. The boom is based on a tubular telescopic concept. Particular emphasis is placed on the payload harness connection capability and safety provisions. *Author*

**N89-23903\*** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

**DESIGN AND DEVELOPMENT OF A HIGH-STIFFNESS, HIGH-RESOLUTION TORQUE SENSOR**

MICHAEL M. SOCHA and BORIS J. LURIE *In NASA, Marshall Space Flight Center, The 23rd Aerospace Mechanisms Symposium p 169-180 Mar. 1989*

Avail: NTIS HC A15/MF A02 CSCL 14/2

A sensor has been designed and tested for precise pointing applications. The device is able to sense extremely small rotary motion and is immune to cross-axis forces. The hardware and design characteristics of the torque sensor are presented. Test data, integrated control methodology, and future applications are included. *Author*

**N89-23906\*** Oak Ridge National Lab., TN.  
**TRACTION-DRIVE FORCE TRANSMISSION FOR TELEROBOTIC JOINTS**

D. M. WILLIAMS and D. P. KUBAN *In NASA, Marshall Space Flight Center, The 23rd Aerospace Mechanisms Symposium p 207-222 Mar. 1989*

Avail: NTIS HC A15/MF A02 CSCL 13/9

A mechanism which meets the requirements of a teleoperated manipulator and those of an autonomous robot is discussed. The mechanism is a traction-drive differential that uses variable preload mechanisms. The differential provides compact design, with dextrous motion range and torque density similar to geared systems. The traction drive offers high stiffness to backlash for

good robotic performance. The variable-loading mechanism (VLM) minimizes the drive-train friction for improved teleoperation. This combination provides a mechanism to allow advanced manipulation with either teleoperated control or autonomous robotic operation. The design principles of both major components of the joint mechanism are described. *Author*

**N89-23907\*** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

**FLIGHT TELEROBOT MECHANISM DESIGN: PROBLEMS AND CHALLENGES**

JOHN B. DAHLGREN and EDWIN P. KAN *In NASA, Marshall Space Flight Center, The 23rd Aerospace Mechanisms Symposium p 223-239 Mar. 1989*

Avail: NTIS HC A15/MF A02 CSCL 13/9

Problems and challenges of designing flight telerobot mechanisms are discussed. Specific experiences are drawn from the following system developments: (1) the Force Reflecting Hand Controller, (2) the Smart End Effector, (3) the force-torque sensor, and a generic multi-degrees-of-freedom manipulator. *Author*

**N89-24389\*** TecnoSpazio S.p.A., Milan (Italy).

**MULTIPLE ROBOT APPROACH FOR AUTOMATION OF IN-ORBIT MODULES**

P. G. MAGNANI, G. COLOMBINA, and C. GERLI *In ESA, International Symposium on Europe in Space: The Manned Space System p 485-492 Oct. 1988*

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Internal automation of in-orbit modules is considered. Logistics and maintenance requirements are defined. Functional, operational, and safety requirements are listed. Mono and multiple robot solutions are compared, and it is concluded that multiple robots are preferable, in spite of the greater simplicity of monorobot solutions. Fixed manipulators; rail-based robots; climbing robots; reconfigurable systems; and multi moving arms are described. *ESA*

**N89-24391\*** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.).

**ROBOTIC EXPERIMENTS ON SPACELAB D-2 AS TESTBED FOR FUTURE OPERATIONAL CONCEPTS**

K. L. MUELLER and M. TURK *In ESA, International Symposium on Europe in Space: The Manned Space System p 503-507 Oct. 1988*

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The Spacelab D2 Robotic Technology Experiment (ROTEX), particularly the robotic arm, is described, and aspects of ROTEX relevant to Columbus are summarized. The ROTEX features relevant to Columbus payload operations include command uplink with higher data rates and less delay than in previous Spacelab missions; high quality TV pictures with predictive graphics superimposed; sole responsibility of ground teams for experiment performance; and use of expert systems for malfunction diagnostics and failure compensation. *ESA*

**N89-24393\*** Dortmund Univ. (Germany, F.R.). Inst. fuer Roboterforschung.

**HIERARCHICALLY STRUCTURED CONTROL FOR INTELLIGENT ROBOTS IN SPACE**

E. FREUND *In ESA, International Symposium on Europe in Space: The Manned Space System p 515-522 Oct. 1988*

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The use of robots in space is discussed and the application of multirobot systems is described. It is argued that a hierarchically structured, modular concept of automation is needed. Critical research areas are sensors and intelligent multisensor systems; teleoperation and man-machine interface; application of expert systems to space-based robots; and multiple arm and mobile robots. *ESA*

**N89-24882\*** Massachusetts Inst. of Tech., Cambridge. Dept. of Mechanical Engineering.

**DYNAMICS OF FLEXIBLE MULTI-BODY MECHANISMS AND MANIPULATORS. PART 1: AN OVERVIEW**

STEVEN DUBOWSKY In NASA, Langley Research Center, Computational Methods for Structural Mechanics and Dynamics p 455-458 May 1989

Avail: NTIS HC A12/MF A02 CSCL 13/9

Flexibility can be a major limitation to the performance of high performance conventional machine systems. The current status of robotic manipulators is limited by the effects of system flexibility. The status of current commercial robots, anticipated development in 5 and 10 years is outlined. B.G.

**N89-24884\*** Iowa Univ., Iowa City. Coll. of Engineering.

**DYNAMICS OF ARTICULATED STRUCTURES**

EDWARD J. HAUG In NASA, Langley Research Center, Computational Methods for Structural Mechanics and Dynamics p 491-515 May 1989

Avail: NTIS HC A12/MF A02 CSCL 13/9

An articulated structure is defined as an assembly of flexible bodies that may be coupled by kinematic connections and force elements that permit large relative displacement and rotation. Kinematics of such systems is defined using one reference frame for each body in the system and deformation modal coordinates that define displacement fields within flexible bodies. Deformation kinematics are defined by both elastic vibration and static correction deformation modes. Linear elastic deformation is presumed; i.e., a linear stress-strain relation is valid and relative displacements within each elastic component are small enough so that the theory of linear elasticity applies. Coupling of reference and modal coordinates leads to a system of nonlinear equations of motion. Methods of automatically generating and solving these equations of motion are outlined. Author

**N89-24821\*** Teledyne Brown Engineering, Huntsville, AL.

**THE IMPACT OF AN IVA ROBOT ON THE SPACE STATION MICROGRAVITY ENVIRONMENT Abstract Only**

PHILLIP E. HARMAN In Tactical Weapons Guidance and Control Information Conference on Space and Military Applications of Automation and Robotics p 4 Jun. 1988

Avail: NTIS HC A05/MF A01 CSCL 09/2

In order to maintain a microgravity environment during Space Station operations, it will be necessary to minimize reaction forces. These mechanical forces will typically result during reboost, docking, equipment operation, IVA robot operations, or crew activity. The impact of these accelerations on the experiments is described by focusing on those disturbances created by an IVA robot. An explanation of the robot dynamic analysis that was used to generate the forcing function as the input into a finite element model of the U.S. laboratory will be shown. These results will identify the acceleration levels at locations throughout the module in order to assess the impact a robotic system will have on space station operations and the microgravity environment. Results will also be shown for the disturbances created by other sources. The results will help quantify what g-level environment can be obtained on the station and the effect of an IVA robot. A comparison between IVA robot effects and crew motion effects on the low-g environment will be described. Author

**N89-24822\*** Kader Robotics, Inc., Huntsville, AL.

**DUAL-ARM ROBOTS FOR TELEROBOTIC IVA OPERATIONS ON THE SPACE STATION Abstract Only**

M. CARL ZIEMKE, JAC KADER, and LARRY YAWN In Tactical Weapons Guidance and Control Information Conference on Space and Military Applications of Automation and Robotics p 5 Jun. 1988

Avail: NTIS HC A05/MF A01 CSCL 09/2

Sometime during the middle of the next decade, the U.S. Space Station will achieve initial operating capability. The activities will be accomplished or directed by a crew of only eight to ten members. The productivity of this initial crew must be amplified by extensive use of automation and robotics. But in 1985, the

astronauts expressed a strong preference for vital equipment that will be 100 percent capable of manual operation in the event of machine failure. Thus, much of the equipment in the Space Station will probably be designed for operation using controls adapted primarily for the human hand and arm. In many cases, these operations will require use of both hands. Therefore, if a machine normally operated by a robot requires direct human operation, it must be possible to maneuver the robot out of the way to permit direct manual operation. These constraints strongly emphasize the need for dexterous, dual-arm robots for Space Station IVA. One of the problems of operation of a dual-arm robot is the coordination of movement between both arms when they are simultaneously engaged in performing a task. A dual-arm robot design was produced that employs asymmetrical manipulator arms that pivot on a common radius. The advantages of this concept are described. These advantages include compactness, light weight, and reduced tendency toward interarm collisions. Author

**N89-24838\*** Otis Engineering, Sedalia, CO.

**INFLATABLE END EFFECTOR TOOLS Abstract Only**

CARTER K. LORD In Tactical Weapons Guidance and Control Information Conference on Space and Military Applications of Automation and Robotics p 40 Jun. 1988

Avail: NTIS HC A05/MF A01 CSCL 09/2

Two variations of inflatable end effector tools were developed. The primary purpose of developing this technology was to provide the capability of grasping delicate composite structural components for assembly of large structures in space. Several other benefits of this system became apparent during the course of the development effort. The inflatable end effector tools utilize controlled air pressure to inflate a bladder of two distinctive configurations to provide the grasping force. Grasping force can, therefore, be predetermined and set simply by controlling the maximum air pressure for that particular operation. Removal of the air pressure from the system deflates the bladder, releasing the item being grasped and establishing a clearance situation for repositioning of the manipulator. Advantages of the system include simplicity, compliance, variable grasping force capability, absence of point contact loads and cost. The principal disadvantage of the simpler cylindrical probe variation is the requirement for a specified diameter hole in each item to be handled. This handling point requirement is minimal, however, and many items may be handled with this configuration without modification. The telescoping probe variation does not require a specific handling point, and is therefore most versatile, although somewhat more complex. Both variations of inflatable end effector tools are currently being fabricated for testing and evaluation on the Proto-Flight Manipulator Arm. Author

**N89-24843\*** Tech-U-Fit Corp., Alexandria, VA.

**TESTING THE FEASIBILITY OF USING A TELEOPERATED ROBOT FOR REMOTE, DEXTEROUS OPERATIONS Abstract Only**

JOHN A. MOLINO and LINDA J. LANGLEY In Tactical Weapons Guidance and Control Information Conference on Space and Military Applications of Automation and Robotics p 48 Jun. 1988

Avail: NTIS HC A05/MF A01 CSCL 09/2

The feasibility of using a teleoperated robot to perform certain procedures associated with nuclear test facilities and space station operations was assessed. Only the space station procedure is reported. The teleoperated robot being evaluated was the Central Research Laboratories' SAMSIN servomanipulator. This device is a seven degrees-of-freedom master/slave remote manipulator with bilateral reflected-force feedback. The ratio of slave/master reflected-force feedback could be varied so that either x0 (none), 4:1 (moderate), or 1:1 (realistic) amounts of reflected force were experienced by the operator. Visual feedback was by means of 3 closed-circuit television monitors. Twenty-eight novice operators were trained to execute the following simulated space station tasks with the SAMSIN teleoperated robot: disassemble and reassemble a space station truss node. This task was accomplished along with four other nuclear-related tasks. The results proved the



feasibility of using a teleoperated robot with a person in the loop to perform a simulated space station-related task. Total system performance (machines, people, training, and procedure) was demonstrated for this truss node operation. Author

**N89-24845#** Teledyne Brown Engineering, Huntsville, AL.  
**GROUND CONTROL OF SPACE BASED ROBOTIC SYSTEMS**  
Abstract Only

K. E. FARNELL and S. F. SPEARING In Tactical Weapons Guidance and Control Information Conference on Space and Military Applications of Automation and Robotics p 50 Jun. 1988

Avail: NTIS HC A05/MF A01 CSCL 09/2

The ability to control robotics in space is clearly an established art with the success of numerous unmanned space probes by both the U.S. and the U.S.S.R. However, these vehicles, such as the Lunakhod and Voyager, were designed to perform discrete functions, and months and years of analysis and programming were required to confidently accomplish even simple planned functions. With the advent of Space Station operations, there will be many instances where robotics will be needed to respond quickly to variable sets of environmental parameters. A system for ground control of space robotic systems is presented and the various control paradigms and operational modes are discussed. The safety aspects, operational constraints and design considerations for robotics operation in a manned environment are discussed.

Author

**N89-25268\*#** North Carolina Univ., Charlotte. Dept. of Mechanical Engineering and Engineering Science.

**DESIGN OF AN AUTO CHANGE MECHANISM AND INTELLIGENT GRIPPER FOR THE SPACE STATION Final Report**

PAUL H. DEHOFF and DIPAK P. NAIK 1989 55 p

(Contract NAG5-922)

(NASA-CR-185387; NAS 1.26:185387) Avail: NTIS HC A04/MF A01 CSCL 22/2

Robot gripping of objects in space is inherently demanding and dangerous and nowhere is this more clearly reflected than in the design of the robot gripper. An object which escapes the gripper in a micro g environment is launched not dropped. To prevent this, the gripper must have sensors and signal processing to determine that the object is properly grasped, e.g., grip points and gripping forces and, if not, to provide information to the robot to enable closed loop corrections to be made. The sensors and sensor strategies employed in the NASA/GSFC Split-Rail Parallel Gripper are described. Objectives and requirements are given followed by the design of the sensor suite, sensor fusion techniques and supporting algorithms. Author

**N89-25461#** Oak Ridge National Lab., TN.  
**TRACTION-DRIVE TRANSMISSION FOR TELEROBOTIC JOINTS**

D. P. KUBAN and D. M. WILLIAMS 1989 14 p Presented at the 23th Aerospace Mechanisms Symposium, Huntsville, AL, 3 May 1989

(Contract DE-AC05-84OR-21400)

(DE89-005337; CONF-890571-1) Avail: NTIS HC A03/MF A01

The U.S. Space Station Program is providing many technological developments to meet the increasing demands of designing such a facility. One of the key areas of research is that of telerobotics for space station assembly and maintenance. Initial implementation will be teleoperated, but long-term plans call for autonomous robotics. One of the essential components for making this transition successful is the manipulator joints mechanism. Historically, teleoperated manipulators and industrial robotics have had very different mechanisms for force transmission. This is because the design objectives are almost mutually exclusive. A teleoperator must have very low friction and inertia to minimize operator fatigue; backlash and stiffness are of secondary concern. A robot, however, must have minimum backlash, and high stiffness for accurate and rapid positioning. A joint mechanism has yet to be developed that can optimize these divergent performance

objectives. A joint mechanism that approaches this optimal performance was developed for NASA Langley, Automation Technology Branch. It is a traction-drive differential that uses variable preload mechanisms. The differential provides compact, dexterous motion range with a torque density similar to geared systems. The traction drive offers high stiffness and zero backlash—for good robotic performance, and the variable-loading mechanism (VLM) minimizes the drive-train friction—for improved teleoperation. DOE

**N89-25639\*#** Oak Ridge National Lab., TN. Instrumentation and Controls Div.

**SYNTHETIC ORGANISMS AND SELF-DESIGNING SYSTEMS**

W. B. DRESS 1989 13 p Presented at the Goddard AI Conference, Greenbelt, MD, 16 May 1989

(Contract DE-AC05-84OR-21400)

(NASA-CR-185324; NAS 1.26:185324; DE89-010318;

CONF-8905130-1) Avail: NTIS HC A03/MF A01 CSCL 09/2

This paper examines the need for complex, adaptive solutions to certain types of complex problems typified by the Strategic Defense System and NASA's Space Station and Mars Rover. Since natural systems have evolved with capabilities of intelligent behavior in complex, dynamic situations, it is proposed that biological principles be identified and abstracted for application to certain problems now facing industry defense, and space exploration. Two classes of artificial neural networks are presented: a non-adaptive network used as a genetically determined retina, and a frequency-coded network as an adaptive brain. The role of a specific environment coupled with a system of artificial neural networks having simulated sensors and effectors is seen as an ecosystem. Evolution of synthetic organisms within this ecosystem provides a powerful optimization methodology for creating intelligent systems able to function successfully in any desired environment. A complex software system involving a simulation of an environment and a program designed to cope with that environment are presented. Reliance on adaptive systems, as found in nature, is only part of the proposed answer, though an essential one. The second part of the proposed method makes use of an additional biological metaphor—that of natural selection—to solve the dynamic optimization problems that every intelligent system eventually faces. A third area of concern in developing an adaptive, intelligent system is that of real-time computing. It is recognized that many of the problems now being explored in this area have their parallels in biological organisms, and many of the performance issues facing artificial neural networks may find resolution in the methodology of real-time computing. DOE

**N89-26017\*#** Vanderbilt Univ., Nashville, TN. Dept. of Electrical Engineering.

**AN AUTOMATION SIMULATION TESTBED Report, Oct. 1987 - Sep. 1988**

GEORGE E. COOK, JANOS SZTIPANOVITS, CSABA BIEGL, GABOR KARSAI, JAMES F. SPRINGFIELD, and ATHEEL MUTAMMARA Sep. 1988 114 p Original contains color illustrations

(Contract NAG8-690)

(NASA-CR-185444; NAS 1.26:185444) Avail: NTIS HC A06/MF A01 CSCL 14/2

The work being done in porting ROBOSIM (a graphical simulation system developed jointly by NASA-MSC and Vanderbilt University) to the HP350SPX graphics workstation is described. New additional ROBOSIM features, like collision detection and new kinematics simulation methods are also discussed. Based on the experiences of the work on ROBOSIM, a new graphics structural modeling environment is suggested which is intended to be a part of a new knowledge-based multiple aspect modeling testbed. The knowledge-based modeling methodologies and tools already available are described. Three case studies in the area of Space Station automation are also reported. First a geometrical structural model of the station is presented. This model was developed using the ROBOSIM package. Next the possible application areas of an integrated modeling environment in the testing of different Space Station operations are discussed. One

of these possible application areas is the modeling of the Environmental Control and Life Support System (ECLSS), which is one of the most complex subsystems of the station. Using the multiple aspect modeling methodology, a fault propagation model of this system is being built and is described. K.C.D.

**N89-26454\*** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

**PROCEEDINGS OF THE WORKSHOP ON SPACE TELEROBOTICS, VOLUME 1**

G. RODRIGUEZ, ed. 1 Jul. 1987 365 p Workshop held in Pasadena, CA, 20-22 Jan. 1987; sponsored by NASA, Washington, DC

(NASA-CR-184685; JPL-PUBL-87-13-VOL-1; NAS 1.26:184685)

Avail: NTIS HC A16/MF A03 CSCL 09/2

These proceedings report the results of a workshop on space telerobotics, which was held at the Jet Propulsion Laboratory, January 20-22, 1987. Sponsored by the NASA Office of Aeronautics and Space Technology (OAST), the Workshop reflected NASA's interest in developing new telerobotics technology for automating the space systems planned for the 1990s and beyond. The workshop provided a window into NASA telerobotics research, allowing leading researchers in telerobotics to exchange ideas on manipulation, control, system architectures, artificial intelligence, and machine sensing. One of the objectives was to identify important unsolved problems of current interest. The workshop consisted of surveys, tutorials, and contributed papers of both theoretical and practical interest. Several sessions were held on the themes of sensing and perception, control execution, operator interface, planning and reasoning, and system architecture.

**N89-26455\*** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

**BUILDING INTELLIGENT SYSTEMS: ARTIFICIAL INTELLIGENCE RESEARCH AT NASA AMES RESEARCH CENTER**

P. FRIEDLAND and H. LUM In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 1 p 19-25 1 Jul. 1987 Previously announced in IAA as A88-15300

Avail: NTIS HC A16/MF A03 CSCL 09/2

The basic components that make up the goal of building autonomous intelligent systems are discussed, and ongoing work at the NASA Ames Research Center is described. It is noted that a clear progression of systems can be seen through research settings (both within and external to NASA) to Space Station testbeds to systems which actually fly on the Space Station. The starting point for the discussion is a truly autonomous Space Station intelligent system, responsible for a major portion of Space Station control. Attention is given to research in fiscal 1987, including reasoning under uncertainty, machine learning, causal modeling and simulation, knowledge from design through operations, advanced planning work, validation methodologies, and hierarchical control of and distributed cooperation among multiple knowledge-based systems. Author

**N89-26456\*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

**SPACE TELEROBOTIC SYSTEMS: APPLICATIONS AND CONCEPTS**

L. JENKINS In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 1 p 29-34 1 Jul. 1987

Avail: NTIS HC A16/MF A03 CSCL 13/9

The definition of a variety of assembly, servicing, and maintenance missions has led to the generation of a number of space telerobot concepts. The remote operation of a space telerobot is seen as a means to increase astronaut productivity. Dexterous manipulator arms are controlled from the Space Shuttle Orbiter cabin or a Space Station module. Concepts for the telerobotic work system have been developed by the Lyndon B. Johnson Space Center through contracts with the Grumman Aerospace Corporation and Martin Marietta Corporation. These

studies defined a concept for a telerobot with extravehicular activity (EVA) astronaut equivalent capability that would be controlled from the Space Shuttle. An evolutionary development of the system is proposed as a means of incorporating technology advances. Early flight testing is seen as needed to address the uncertainties of robotic manipulation in space. Space robotics can be expected to spin off technology to terrestrial robots, particularly in hazardous and unstructured applications. Author

**N89-26457\*** Boeing Aerospace Co., Huntsville, AL. **LABORATORY TESTING OF CANDIDATE ROBOTIC APPLICATIONS FOR SPACE**

R. B. PURVES In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 1 p 35-44 1 Jul. 1987

Avail: NTIS HC A16/MF A03 CSCL 13/9

Robots have potential for increasing the value of man's presence in space. Some categories with potential benefit are: (1) performing extravehicular tasks like satellite and station servicing, (2) supporting the science mission of the station by manipulating experiment tasks, and (3) performing intravehicular activities which would be boring, tedious, exacting, or otherwise unpleasant for astronauts. An important issue in space robotics is selection of an appropriate level of autonomy. In broad terms three levels of autonomy can be defined: (1) teleoperated - an operator explicitly controls robot movement; (2) telerobotic - an operator controls the robot directly, but by high-level commands, without, for example, detailed control of trajectories; and (3) autonomous - an operator supplies a single high-level command, the robot does all necessary task sequencing and planning to satisfy the command. Researchers chose three projects for their exploration of technology and implementation issues in space robots, one each of the three application areas, each with a different level of autonomy. The projects were: (1) satellite servicing - teleoperated; (2) laboratory assistant - telerobotic; and (3) on-orbit inventory manager - autonomous. These projects are described and some results of testing are summarized. Author

**N89-26458\*** Grumman Aerospace Corp., Bethpage, NY. Space Systems Div.

**TELEROBOTIC ASSEMBLY OF SPACE STATION TRUSS STRUCTURES**

G. FISCHER In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 1 p 45-53 1 Jul. 1987 Previously announced as N87-18984

Avail: NTIS HC A16/MF A03 CSCL 22/2

Discussed here are methods of assembling the space station's structure utilizing only telerobotic devices, i.e.: (1) an approximately anthropomorphic telerobot with two dextrous arms; (2) the Shuttle Remote Manipulator System (SRMS); and (3) various material handling machines. Timelines and task recommendations for autonomous operations are also included. Also described are some experimental results comparing two manipulator control devices. Author

**N89-26459\*** Lockheed Missiles and Space Co., Sunnyvale, CA.

**ROBOTIC MOBILE SERVICING PLATFORM FOR SPACE STATION**

S. H. LOWENTHAL and L. VANERDEN In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 1 p 55-65 1 Jul. 1987

Avail: NTIS HC A16/MF A03 CSCL 22/2

The semi-autonomous inspection and servicing of the Space Station's major thermal, electrical, mechanical subsystems are critical needs for the safe and reliable operation of the station. A conceptual design is presented of a self-intelligent, small and highly mobile robotic platform. Equipped with suitable inspection sensors (cameras, ammonia detectors, etc.), this system's primary mission is to perform routine, autonomous inspection of the Station's primary subsystems. Typical tasks include detection of leaks from thermal fluid or refueling lines, as well as detection of micro-meteoroid damage to the primary structure. Equipped with

stereo cameras and a dexterous manipulator, simple teleoperator repairs and small On-orbit Replacement Unit (ORU) changeout can also be accomplished. More difficult robotic repairs would be left to the larger, more sophisticated Mobile Remote Manipulator System (MRMS). An ancillary function is to ferry crew members and equipment around the station. The primary design objectives were to provide a flexible, but uncomplicated robotic platform, one which caused minimal impact to the design of the Station's primary structure but could accept more advanced telerobotic technology as it evolves. Author

**N89-26460\*#** California Inst. of Tech., Pasadena.  
**SYSTEM ENGINEERING TECHNIQUES FOR ESTABLISHING  
 BALANCED DESIGN AND PERFORMANCE GUIDELINES FOR  
 THE ADVANCED TELEROBOTIC TESTBED**

W. F. ZIMMERMAN and J. R. MATJUEVIC In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 1 p 67-73 1 Jul. 1987

Avail: NTIS HC A16/MF A03 CSCL 14/2

Novel system engineering techniques have been developed and applied to establishing structured design and performance objectives for the Telerobotics Testbed that reduce technical risk while still allowing the testbed to demonstrate an advancement in state-of-the-art robotic technologies. To establish the appropriate tradeoff structure and balance of technology performance against technical risk, an analytical data base was developed which drew on: (1) automation/robot-technology availability projections, (2) typical or potential application mission task sets, (3) performance simulations, (4) project schedule constraints, and (5) project funding constraints. Design tradeoffs and configuration/performance iterations were conducted by comparing feasible technology/task set configurations against schedule/budget constraints as well as original program target technology objectives. The final system configuration, task set, and technology set reflected a balanced advancement in state-of-the-art robotic technologies, while meeting programmatic objectives and schedule/cost constraints. Author

**N89-26461\*#** Rockwell International Corp., Canoga Park, CA.  
 Rocketdyne Div.

**DEDICATED ROBOTIC SERVICING FOR THE SPACE STATION**  
 R. F. THOMPSON, G. ARNOLD, and D. GUTOW In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 1 p 75-82 1 Jul. 1987

Avail: NTIS HC A16/MF A03 CSCL 22/2

The concept of a series of dedicated robotics manipulators that would be resident in the subsystems of the Space Station is presented. These would be used to do Orbital Replacement Unit (ORU) exchanges, inspection of the components, and in certain cases subsystem assembly. By performing these well-defined tasks automatically, higher crew productivity would be achieved. In order to utilize the robots effectively, ORU's must be designed to allow remote release and quick disconnection of the electrical, fluid, and thermal connections. The robot must be of a modular design for ease of maintenance and must have an adaptive control capability to make-up for slight errors in programming. Author

**N89-26462\*#** Martin Marietta Aerospace, Denver, CO.

**SHUTTLE BAY TELEROBOTICS DEMONSTRATION**  
 W. CHUN and P. COGEO In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 1 p 83-90 1 Jul. 1987

Avail: NTIS HC A16/MF A03 CSCL 22/2

A demonstration of NASA's robotics capabilities should be a balanced agenda of servicing and assembly tasks combined with selected key technical experiments. The servicing tasks include refueling and module replacement. Refueling involves the mating of special fluid connectors while module replacement requires an array of robotic technologies such as special tools, the arm of a logistics tool, and the precision mating of orbital replacement units to guides. The assembly task involves the construction of a space station node and truss structure. The technological experiments will focus on a few important issues: the precision manipulation of the arms by a teleoperator, the additional use of several mono

camera views in conjunction with the stereo system, the use of a general purpose end effector versus a caddy of tools, and the dynamics involved with using a robot with a stabilizer. Author

**N89-26463\*#** California Univ., Berkeley.

**TELEROBOTICS: RESEARCH NEEDS FOR EVOLVING SPACE STATIONS**

L. STARK In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 1 p 91-94 1 Jul. 1987

Avail: NTIS HC A16/MF A03 CSCL 22/2

It is argued that triplicate planning for telerobotics applicable to space stations is needed. It is important to carry out research to accomplish tasks: (1) with man alone (such as extra-vehicular activities), (2) with autonomous robots, and (3) with telerobotics. The research necessary to carry out these approaches is compared and contrasted in order to clarify present problems. Author

**N89-26464\*#** California Univ., Santa Barbara.

**ROBOT DESIGN FOR A VACUUM ENVIRONMENT**

S. BELINSKI, W. TRENTO, R. IMANI-SHIKHABADI, and S. HACKWOOD In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 1 p 95-103 1 Jul. 1987 Sponsored in part by Delco Systems Operations

Avail: NTIS HC A16/MF A03 CSCL 13/9

The cleanliness requirements for many processing and manufacturing tasks are becoming ever stricter, resulting in a greater interest in the vacuum environment. Researchers discuss the importance of this special environment, and the development of robots which are physically and functionally suited to vacuum processing tasks. Work is in progress at the Center for Robotic Systems in Microelectronics (CRSM) to provide a robot for the manufacture of a revolutionary new gyroscope in high vacuum. The need for vacuum in this and other processes is discussed as well as the requirements for a vacuum-compatible robot. Finally, researchers present details on work done at the CRSM to modify an existing clean-room compatible robot for use at high vacuum. Author

**N89-26465\*#** Ohio State Univ., Columbus.

**MULTI-LIMBED LOCOMOTION SYSTEMS FOR SPACE CONSTRUCTION AND MAINTENANCE**

K. J. WALDRON and C. A. KLEIN In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 1 p 105-111 1 Jul. 1987  
 (Contract NAG1-30; D4AE07-84-K-R001)

Avail: NTIS HC A16/MF A03 CSCL 13/9

A well developed technology of coordination of multi-limbed locomotory systems is now available. Results from a NASA sponsored study of several years ago are presented. This was a simulation study of a three-limbed locomotion/manipulation system. Each limb had six degrees of freedom and could be used either as a locomotory grasping hand-holds, or as a manipulator. The focus of the study was kinematic coordination algorithms. The presentation will also include very recent results from the Adaptive Suspension Vehicle Project. The Adaptive Suspension Vehicle (ASV) is a legged locomotion system designed for terrestrial use which is capable of operating in completely unstructured terrain in either a teleoperated or operator-on-board mode. Future development may include autonomous operation. The ASV features a very advanced coordination and control system which could readily be adapted to operation in space. An inertial package with a vertical gyro, and rate gyros and accelerometers on three orthogonal axes provides body position information at high bandwidth. This is compared to the operator's commands, injected via a joystick to provide a commanded force system on the vehicle's body. This system is, in turn, decomposed by a coordination algorithm into force commands to those legs which are in contact with the ground. Author



**N89-26471\*** National Bureau of Standards, Gaithersburg, MD.  
**HIERARCHICAL CONTROL OF INTELLIGENT MACHINES  
 APPLIED TO SPACE STATION TELEROBOTS**  
 J. S. ALBUS, R. LUMIA, and H. MCCAIN. In Jet Propulsion Lab.,  
 California Inst. of Tech., Proceedings of the Workshop on Space  
 Telerobotics, Volume 1 p 155-165 1 Jul. 1987  
 Avail: NTIS HC A18/MF A03 CSCL 09/2

A hierarchical architecture is described which supports space station telerobots in a variety of modes. The system is divided into three hierarchies: task decomposition, world model, and sensory processing. Goals at each level of the task decomposition hierarchy are divided both spatially and temporally into simpler commands for the next lower level. This decomposition is repeated until, at the lowest level, the drive signals to the robot actuators are generated. To accomplish its goals, task decomposition modules must often use information stored in the world model. The purpose of the sensory system is to update the world model as rapidly as possible to keep the model in registration with the physical world. The architecture of the entire control system hierarchy and how it can be applied to space telerobot applications are discussed. Author

**N89-26492\*** Jet Propulsion Lab., California Inst. of Tech., Pasadena.  
**PROCEEDINGS OF THE WORKSHOP ON SPACE  
 TELEROBOTICS, VOLUME 2**  
 G. RODRIGUEZ, ed. 1 Jul. 1987 422 p Workshop held in  
 Pasadena, CA, 20-22 Jan. 1987; sponsored by NASA, Washington,  
 DC  
 (NASA-CR-184686; JPL-PUBL-87-13-VOL-2; NAS 1.26:184686)  
 Avail: NTIS HC A18/MF A03 CSCL 09/2

Research on sensing and perception, telerobots, man machine interface, scheduling, trajectory planning for manipulators, and manipulator control is discussed.

**N89-26493\*** Jet Propulsion Lab., California Inst. of Tech., Pasadena.  
**THE SENSING AND PERCEPTION SUBSYSTEM OF THE NASA  
 RESEARCH TELEROBOT**  
 B. WILCOX, D. B. GENNERY, B. BON, and T. LITWIN. In  
 Proceedings of the Workshop on Space Telerobotics, Volume 2 p  
 3-7 1 Jul. 1987  
 Avail: NTIS HC A18/MF A03 CSCL 13/9

A useful space telerobot for on-orbit assembly, maintenance, and repair tasks must have a sensing and perception subsystem which can provide the locations, orientations, and velocities of all relevant objects in the work environment. This function must be accomplished with sufficient speed and accuracy to permit effective grasping and manipulation. Appropriate symbolic names must be attached to each object for use by higher-level planning algorithms. Sensor data and inferences must be presented to the remote human operator in a way that is both comprehensible in ensuring safe autonomous operation and useful for direct teleoperation. Research at JPL toward these objectives is described. Author

**N89-26494\*** Honeywell Systems and Research Center, Minneapolis, MN.  
**KNOWLEDGE-BASED VISION FOR SPACE STATION OBJECT  
 MOTION DETECTION, RECOGNITION, AND TRACKING**  
 P. SYMOSEK, D. PANDA, S. YALAMANCHILI, and W. WEHNER, III. In Jet Propulsion Lab., California Inst. of Tech., Proceedings  
 of the Workshop on Space Telerobotics, Volume 2 p 9-18 1  
 Jul. 1987  
 Avail: NTIS HC A18/MF A03 CSCL 09/2

Computer vision, especially color image analysis and understanding, has much to offer in the area of the automation of Space Station tasks such as construction, satellite servicing, rendezvous and proximity operations, inspection, experiment monitoring, data management and training. Knowledge-based techniques improve the performance of vision algorithms for unstructured environments because of their ability to deal with imprecise a priori information or inaccurately estimated feature data and still produce useful results. Conventional techniques using

statistical and purely model-based approaches lack flexibility in dealing with the variabilities anticipated in the unstructured viewing environment of space. Algorithms developed under NASA sponsorship for Space Station applications to demonstrate the value of a hypothesized architecture for a Video Image Processor (VIP) are presented. Approaches to the enhancement of the performance of these algorithms with knowledge-based techniques and the potential for deployment of highly-parallel multi-processor systems for these algorithms are discussed. Author

**N89-26495\*** Rockwell International Science Center, Thousand Oaks, CA.  
**SENSOR SYSTEMS TESTBED FOR TELEROBOTIC  
 NAVIGATION**  
 A. W. THIELE, D. E. GJELLUM, R. H. RATTNER, and D.  
 MANOUCHEHR. (Rockwell International Corp., Downey, CA.) In  
 Jet Propulsion Lab., California Inst. of Tech., Proceedings of the  
 Workshop on Space Telerobotics, Volume 2 p 19-21 1 Jul.  
 1987  
 (Contract NAS9-17365)  
 Avail: NTIS HC A18/MF A03 CSCL 17/7

A testbed has been developed for the study of sensor systems to be used in telerobotic operations. The program, conducted in conjunction with Johnson Space Center of NASA, addresses the navigational problems associated with target acquisition and rendezvous for teleoperated robotic work stations. The program will utilize a mobile platform which will support various sensor systems during their development and testing in an earth-based environment. The testbed has been developed in support of a program to develop sensor systems that will aid in rendezvous and docking operations to be conducted as a part of the space station program. A mobile platform has been used to permit testing of these components in a conventional laboratory environment with consequent savings in cost and complexity. The sensor systems, while representative of devices currently in use for robotic applications, are not considered prototypical of the ones that will be used in the final applications. The test program provided information that will support the design of system augmentations and will lead to a comprehensive test program for sensor development. Author

**N89-26497\*** Minnesota Univ., Minneapolis.  
**TRACKING 3-D BODY MOTION FOR DOCKING AND ROBOT  
 CONTROL**  
 M. DONATH, B. SORESENSEN, G. B. YANG, and R. STARR. In  
 Jet Propulsion Lab., California Inst. of Tech., Proceedings of the  
 Workshop on Space Telerobotics, Volume 2 p 31-43 1 Jul.  
 1987  
 (Contract NHR-G006300075; NSF DMC-83-51827)  
 Avail: NTIS HC A18/MF A03 CSCL 09/2

An advanced method of tracking three-dimensional motion of bodies has been developed. This system has the potential to dynamically characterize machine and other structural motion, even in the presence of structural flexibility, thus facilitating closed loop structural motion control. The system's operation is based on the concept that the intersection of three planes defines a point. Three rotating planes of laser light, fixed and moving photovoltaic diode targets, and a pipe-lined architecture of analog and digital electronics are used to locate multiple targets whose number is only limited by available computer memory. Data collection rates are a function of the laser scan rotation speed and are currently selectable up to 480 Hz. The tested performance on a preliminary prototype designed for 0.1 in accuracy (for tracking human motion) at a 480 Hz data rate includes a worst case resolution of 0.8 mm (0.03 inches), a repeatability of plus or minus 0.635 mm (plus or minus 0.025 inches), and an absolute accuracy of plus or minus 2.0 mm (plus or minus 0.08 inches) within an eight cubic meter volume with all results applicable at the 95 percent level of confidence along each coordinate region. The full six degrees of freedom of a body can be computed by attaching three or more target detectors to the body of interest. Author

**N89-26499\*** Wisconsin Univ., Madison.

# **SENSORY SUBSTITUTION FOR SPACE GLOVES AND FOR SPACE ROBOTS**

P. BACH-Y-RITA, J. G. WEBSTER, W. J. TOMPKINS, and T. CRABB (Astronautics Corp. of America, Madison, WI.) In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 2 p 51-57 1 Jul. 1987

(Contract NAS6-9171; NAGW-975)

Avail: NTIS HC A18/MF A03 CSCL 09/2

Sensory substitution systems for space applications are described. Physical sensors replace missing human receptors and feed information to the interpretive centers of a different sense. The brain is plastic enough so that, with training, the subject localizes the input as if it were received through the missing receptors. Astronauts have difficulty feeling objects through space suit gloves because of their thickness and because of the 4.3 psi pressure difference. Moisture force sensors on the glove palm drive an electrostatic belt around the waist, thus augmenting the missing tactile sensation. A proposed teleoperator system with telepresence for a space robot would incorporate teleproprioception and a force sensor/electrostatic belt sensory substitution system for teletouch. Author

**N89-26500\*** Cornell Univ., Ithaca, NY.

# **ELECTRONIC PROTOTYPING**

J. HOPCROFT In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 2 p 59-63 1 Jul. 1987

Avail: NTIS HC A18/MF A03 CSCL 09/2

The potential benefits of automation in space are significant. The science base needed to support this automation not only will help control costs and reduce lead-time in the earth-based design and construction of space stations, but also will advance the nation's capability for computer design, simulation, testing, and debugging of sophisticated objects electronically. Progress in automation will require the ability to electronically represent, reason about, and manipulate objects. Discussed here is the development of representations, languages, editors, and model-driven simulation systems to support electronic prototyping. In particular, it identifies areas where basic research is needed before further progress can be made. Author

**N89-26508\*** Rice Univ., Houston, TX.

# **A TECHNIQUE FOR 3-D ROBOT VISION FOR SPACE APPLICATIONS**

V. MARKANDEY, H. TAGARE, and R. J. P. DEFIGUEIREDO In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 2 p 111-123 1 Jul. 1987

(Contract NAS9-17145; NCC9-18; NSF DCR-83-18514)

Avail: NTIS HC A18/MF A03 CSCL 09/2

An extension of the MIAG algorithm for recognition and motion parameter determination of general 3-D polyhedral objects based on model matching techniques and using Moment Invariants as features of object representation is discussed. Results of tests conducted on the algorithm under conditions simulating space conditions are presented. Author

**N89-26516\*** McDonnell-Douglas Aerospace Information Services Co., Saint Louis, MO.

# **REAL-TIME GRAPHIC SIMULATION FOR SPACE Telerobotics APPLICATIONS**

E. W. BAUMANN In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 2 p 207-217 1 Jul. 1987

Avail: NTIS HC A18/MF A03 CSCL 09/2

Designing space-based telerobotic systems presents many problems unique to telerobotics and the space environment, but it also shares many common hardware and software design problems with Earth-based industrial robot applications. Such problems include manipulator design and placement, grapple-fixture design, and of course the development of effective and reliable control

algorithms. Since first being applied to industrial robotics just a few years ago, interactive graphic simulation has proven to be a powerful tool for anticipating and solving problems in the design of Earth-based robotic systems and processes. Where similar problems are encountered in the design of space-based robotic mechanisms, the same graphic simulation tools may also be of assistance. The capabilities of PLACE, a commercially available interactive graphic system for the design and simulation of robotic systems and processes is described. A space-telerobotics application of the system is presented and discussed. Potential future enhancements are described. Author

**N89-26517\*** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

# **MANIPULATOR CONTROL AND MECHANIZATION: A Telerobot SUBSYSTEM**

S. HAYATI and B. WILCOX In its Proceedings of the Workshop on Space Telerobotics, Volume 2 p 219-227 1 Jul. 1987

Avail: NTIS HC A18/MF A03 CSCL 13/9

The short- and long-term autonomous robot control activities in the Robotics and Teleoperators Research Group at the Jet Propulsion Laboratory (JPL) are described. This group is one of several involved in robotics and is an integral part of a new NASA robotics initiative called Telerobot program. A description of the architecture, hardware and software, and the research direction in manipulator control is given. Author

**N89-26521\*** California Univ., Los Angeles.

# **CONTROL STRATEGY FOR A DUAL-ARM MANEUVERABLE SPACE ROBOT**

P. K. C. WANG In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 2 p 257-266 1 Jul. 1987

Avail: NTIS HC A18/MF A03 CSCL 13/9

A simple strategy for the attitude control and arm coordination of a maneuverable space robot with dual arms is proposed. The basic task for the robot consists of the placement of marked rigid solid objects with specified pairs of gripping points and a specified direction of approach for gripping. The strategy consists of three phases each of which involves only elementary rotational and translational collision-free maneuvers of the robot body. Control laws for these elementary maneuvers are derived by using a body-referenced dynamic model of the dual-arm robot. Author

**N89-26524\*** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

# **A FLEXIBLE Telerobotic SYSTEM FOR SPACE OPERATIONS**

N. O. SUWA and R. W. WILL In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 2 p 285-292 1 Jul. 1987 Previously announced in IAA as A87-23229

Avail: NTIS HC A18/MF A03 CSCL 13/9

The objective and design of a proposed goal-oriented knowledge-based telerobotic system for space operations is described. This design effort encompasses the elements of the system executive and user interface and the distribution and general structure of the knowledge base, the displays, and the task sequencing. The objective of the design effort is to provide an expandable structure for a telerobotic system that provides cooperative interaction between the human operator and computer control. The initial phase of the implementation provides a rule-based, goal-oriented script generator to interface to the existing control modes of a telerobotic research system, in the Intelligent Systems Research Lab at NASA Research Center. Author

**N89-26525\*** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

# **SYSTEMS SIMULATIONS SUPPORTING NASA Telerobotics**

F. W. HARRISON, JR. and J. E. PENNINGTON In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on

Space Telerobotics, Volume 2 p 293-299 1 Jul. 1987 Previously announced in IAA as A87-23227

Avail: NTIS HC A18/MF A03 CSCL 09/2

Two simulation and analysis environments have been developed to support telerobotics research at the Langley Research Center. One is a high-fidelity, nonreal-time, interactive model called ROBSIM, which combines user-generated models of workspace environment, robots, and loads into a working system and simulates the interaction among the system components. Models include user-specified actuator, sensor, and control parameters, as well as kinematic and dynamic characteristics. Kinematic, dynamic, and response analyses can be selected, with system configuration, task trajectories, and arm states displayed using computer graphics. The second environment is a real-time, manned Telerobotic Systems Simulation (TRSS) which uses the facilities of the Intelligent Systems Research Laboratory (ISRL). It utilizes a hierarchical structure of functionally distributed computers communicating over both parallel and high-speed serial data paths to enable studies of advanced telerobotic systems. Multiple processes perform motion planning, operator communications, forward and inverse kinematics, control/sensor fusion, and I/O processing while communicating via common memory. Both ROBSIM and TRSS, including their capability, status, and future plans are discussed. Also described is the architecture of ISRL and recent telerobotic system studies in ISRL. Author

**N89-26528\*#** Martin Marietta Aerospace, Denver, CO.  
**A TASK-BASED METRIC FOR TELEROBOTIC PERFORMANCE ASSESSMENT**

J. F. BARNES In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 2 p 317-324 1 Jul. 1987

Avail: NTIS HC A18/MF A03 CSCL 13/9

A methodology is described for developing a task complexity index based on combining the six basic motion primitives (three translation, three orientation) with force control and accuracy requirements. The result of this development is a set of complexity values that can be assigned to the high-level task primitives derived from a relatively shallow top-down mission analysis. These values are then averaged to arrive at total average mission complexities, such as for the mission of exchanging the Hubble Space Telescope (HST) battery modules. Application of this metric to a candidate set of NASA Flight Telerobotic Servicer evaluation tasks is discussed using the HST battery module mission for an in-depth example. Author

**N89-26530\*#** ORINTEC, Vallejo, CA.  
**USE OF CONTROL UMBILICALS AS A DEPLOYMENT MODE FOR FREE FLYING TELEROBOTIC WORK SYSTEMS**

J. S. KUEHN and E. D. SELLE In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 2 p 335-339 1 Jul. 1987

Avail: NTIS HC A18/MF A03 CSCL 13/9

Work to date on telerobotic work systems for use in space generally consider two deployment modes, free flying, or fixed within a limited work envelope. Control tethers may be employed to obtain a number of operational advantages and added flexibility in the basing and deployment of telerobotic work systems. Use of a tether allows the work system to be separated into two major modules, the remote work package and the control module. The Remote Work Package (RWP) comprises the free flying portion of the work system while the Control Module (CM) remains at the work system base. The chief advantage of this configuration is that only the components required for completion of the work task must be located at the work site. Reaction mass used in free flight is stored at the Control module and supplied to the RWP through the tether, eliminating the need for the RWP to carry it. The RWP can be made less massive than a self contained free flying work system. As a result, reaction mass required for free flight is lower than for a self contained free flyer. Author

**N89-26533\*#** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

**MAN-MACHINE INTERFACE ISSUES IN SPACE TELEROBOTICS: A JPL RESEARCH AND DEVELOPMENT PROGRAM**

A. K. BEJCZY In its Proceedings of the Workshop on Space Telerobotics, Volume 2 p 361-369 1 Jul. 1987

Avail: NTIS HC A18/MF A03 CSCL 05/8

Technology issues related to the use of robots as man-extension or telerobot systems in space are discussed and exemplified. General considerations are presented on control and information problems in space teleoperation and on the characteristics of Earth orbital teleoperator. The JPL R and D work in the area of man-machine interface devices and techniques for sensing and computer-based control is briefly summarized. The thrust of this R and D effort is to render space teleoperation efficient and safe through the use of devices and techniques which will permit integrated and task-level (intelligent) two-way control communication between human operator and telerobot machine in Earth orbit. Specific control and information display devices and techniques are discussed and exemplified with development results obtained at JPL in recent years. Author

**N89-26541\*#** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

**PROCEEDINGS OF THE WORKSHOP ON SPACE TELEROBOTICS, VOLUME 3**

G. RODRIGUEZ, ed. 1 Jul. 1987 412 p Workshop held in Pasadena, CA, 20-22 Jan. 1987; sponsored by NASA, Washington, DC (NASA-CR-184687; JPL-PUBL-87-13-VOL-3; NAS 1.26:184687)

Avail: NTIS HC A18/MF A03 CSCL 09/2

Planning and scheduling for robot applications, trajectory planning for manipulators, and manipulator control are discussed.

**N89-26544\*#** Stanford Research Inst., Menlo Park, CA.  
**REASONING AND PLANNING IN DYNAMIC DOMAINS: AN EXPERIMENT WITH A MOBILE ROBOT**

M. P. GEORGEFF, A. L. LANSKY, and M. J. SCHOPPERS In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 3 p 27-39 1 Jul. 1987

(Contract N00014-85-C-0251; FMC-147466)

Avail: NTIS HC A18/MF A03 CSCL 09/2

Progress made toward having an autonomous mobile robot reason and plan complex tasks in real-world environments is described. To cope with the dynamic and uncertain nature of the world, researchers use a highly reactive system to which is attributed attitudes of belief, desire, and intention. Because these attitudes are explicitly represented, they can be manipulated and reasoned about, resulting in complex goal-directed and reflective behaviors. Unlike most planning systems, the plans or intentions formed by the system need only be partly elaborated before it decides to act. This allows the system to avoid overly strong expectations about the environment, overly constrained plans of action, and other forms of over-commitment common to previous planners. In addition, the system is continuously reactive and has the ability to change its goals and intentions as situations warrant. Thus, while the system architecture allows for reasoning about means and ends in much the same way as traditional planners, it also possesses the reactivity required for survival in complex real-world domains. The system was tested using SRI's autonomous robot (Flakey) in a scenario involving navigation and the performance of an emergency task in a space station scenario. Author

**N89-26554\*#** Carnegie-Mellon Univ., Pittsburgh, PA.  
**TASK PLANNING AND CONTROL SYNTHESIS FOR ROBOTIC MANIPULATION IN SPACE APPLICATIONS**

A. C. SANDERSON, M. A. PESHKIN, and L. S. HOMEM-DE-MELLO In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics,



Volume 3 p 129-136 1 Jul. 1987  
 Avail: NTIS HC A18/MF A03 CSCL 09/2

Space-based robotic systems for diagnosis, repair and assembly of systems will require new techniques of planning and manipulation to accomplish these complex tasks. Results of work in assembly task representation, discrete task planning, and control synthesis which provide a design environment for flexible assembly systems in manufacturing applications, and which extend to planning of manipulation operations in unstructured environments are summarized. Assembly planning is carried out using the AND/OR graph representation which encompasses all possible partial orders of operations and may be used to plan assembly sequences. Discrete task planning uses the configuration map which facilitates search over a space of discrete operations parameters in sequential operations in order to achieve required goals in the space of bounded configuration sets. Author

**N89-26555\*#** Massachusetts Inst. of Tech., Cambridge.  
**UL NG AUTOMATIC ROBOT PROGRAMMING FOR SPACE Telerobotics**

E. MAZER, J. JONES, A. LANUSSE, T. LOZANO-PEREZ, P. O'DONNELL, and P. TOURNAISSAUD In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 3 p 139-150 1 Jul. 1987 Sponsored in part by NSF; and by the Centre National de la Recherche Scientifique (France)  
 (Contract N00014-85-K-0214)

Avail: NTIS HC A18/MF A03 CSCL 09/2

The interpreter of a task level robot programming system called Handey is described. Handey is a system that can recognize, manipulate and assemble polyhedral parts when given only a specification of the goal. To perform an assembly, Handey makes use of a recognition module, a gross motion planner, a grasp planner, a local approach planner and is capable of planning part re-orientation. The possibility of including these modules in a telerobotics work-station is discussed. Author

**N89-26556\*#** Carnegie-Mellon Univ., Pittsburgh, PA.  
**DESIGN OF A RECONFIGURABLE MODULAR MANIPULATOR SYSTEM**

D. SCHMITZ and T. KANADE In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 3 p 171-178 1 Jul. 1987

Avail: NTIS HC A18/MF A03 CSCL 13/9

Using manipulators with a fixed configuration for specific tasks is appropriate when the task requirements are known beforehand. However, in less predictable situations, such as an outdoor construction site or aboard a space station, a manipulator system requires a wide range of capabilities, probably beyond the limitations of a single, fixed-configuration manipulator. To fulfill this need, researchers have been working on a Reconfigurable Modular Manipulator System (RMMS). Researchers have designed and are constructing a prototype RMMS. The prototype currently consists of two joint modules and four link modules. The joints utilize a conventional harmonic drive and torque motor actuator, with a small servo amplifier included in the assembly. A brushless resolver is used to sense the joint position and velocity. For coupling the modules together, a standard electrical connector and V-band clamps for mechanical connection are used, although more sophisticated designs are under way for future versions. The joint design yields an output torque to 50 ft-lbf at joint speeds up to 1 radian/second. The resolver and associated electronics have resolutions of 0.0001 radians, and absolute accuracies of plus or minus 0.001 radians. Manipulators configured from these prototype modules will have maximum reaches in the 0.5 to 2 meter range. The real-time RMMS controller consists of a Motorola 68020 single-board computer which will perform real time servo control and path planning of the manipulator. This single board computer communicates via shared memory with a SUN3 workstation, which serves as a software development system and robot programming environment. Researchers have designed a bus communication network to provide multiplexed communication between the joint modules and the computer controller. The bus supports

identification of modules, sensing of joint states, and commands to the joint actuator. This network has sufficient bandwidth to allow servo sampling rates in excess of 500 Hz. Author

**N89-26564\*#** Queensland Univ., Saint Lucia (Australia).  
**ALGORITHMS FOR ADAPTIVE CONTROL OF TWO-ARM FLEXIBLE MANIPULATORS UNDER UNCERTAINTY**

J. M. SKOWRONSKI In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 3 p 245-253 1 Jul. 1987

Avail: NTIS HC A18/MF A03 CSCL 09/2

A nonlinear extension of model reference adaptive control (MRAC) technique is used to guide a double arm nonlinearizable robot manipulator with flexible links, driven by actuators collocated with joints subject to uncertain payload and inertia. The objective is to track a given simple linear and rigid but compatible dynamical model in real, possible stipulated time and within stipulated degree of accuracy of convergence while avoiding collision of the arms. The objective is attained by a specified signal adaptive feedback controller and by adaptive laws, both given in closed form. A case of 4 DOF manipulator illustrates the technique. Author

**N89-26568\*#** Ohio State Univ., Columbus.  
**FLEXIBLE MANIPULATOR CONTROL EXPERIMENTS AND ANALYSIS**

S. YURKOVICH, U. OZGUNER, A. TZES, and P. T. KOTNIK In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 3 p 279-287 1 Jul. 1987

Avail: NTIS HC A18/MF A03 CSCL 09/2

Modeling and control design for flexible manipulators, both from an experimental and analytical viewpoint, are described. From the application perspective, an ongoing effort within the laboratory environment at the Ohio State University, where experimentation on a single link flexible arm is underway is described. Several unique features of this study are described here. First, the manipulator arm is slewed by a direct drive dc motor and has a rigid counterbalance appendage. Current experimentation is from two viewpoints: (1) rigid body slewing and vibration control via actuation with the hub motor, and (2) vibration suppression through the use of structure-mounted proof-mass actuation at the tip. Such an application to manipulator control is of interest particularly in design of space-based telerobotic control systems, but has received little attention to date. From an analytical viewpoint, parameter estimation techniques within the closed-loop for self-tuning adaptive control approaches are discussed. Also introduced is a control approach based on output feedback and frequency weighting to counteract effects of spillover in reduced-order model design. A model of the flexible manipulator based on experimental measurements is evaluated for such estimation and control approaches. Author

**N89-26569\*#** Ohio State Univ., Columbus.  
**DUAL ARM ROBOTIC SYSTEM WITH SENSORY INPUT**

U. OZGUNER In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 3 p 289-297 1 Jul. 1987

Avail: NTIS HC A18/MF A03 CSCL 13/9

The need for dual arm robots in space station assembly and satellite maintenance is of increasing significance. Such robots will be in greater demand in the future when numerous tasks will be assigned to them to relieve the direct intervention of humans in space. Technological demands from these robots will be high. They will be expected to perform high speed tasks with a certain degree of autonomy. Various levels of sensing will have to be used in a sophisticated control scheme. Ongoing research in control, sensing and real-time software to produce a two-arm robotic system that can accomplish generic assembly tasks is discussed. The control hierarchy and the specific control approach are discussed. A decentralized implementation of model-reference adaptive control using Variable Structure controllers and the incorporation of tactile feedback is considered. Author

**N89-26571\*** Old Dominion Univ., Norfolk, VA.

**REDUCING MODEL UNCERTAINTY EFFECTS IN FLEXIBLE MANIPULATORS THROUGH THE ADDITION OF PASSIVE DAMPING**

T. E. ALBERTS In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 3 p 307-316 1 Jul. 1987 Prepared in cooperation with Georgia Inst. of Tech., Atlanta

Avail: NTIS HC A18/MF A03 CSCL 13/5

An important issue in the control of practical systems is the effect of model uncertainty on closed loop performance. This is of particular concern when flexible structures are to be controlled, due to the fact that states associated with higher frequency vibration modes are truncated in order to make the control problem tractable. Digital simulations of a single-link manipulator system are employed to demonstrate that passive damping added to the flexible member reduces adverse effects associated with model uncertainty. A controller was designed based on a model including only one flexible mode. This controller was applied to larger order systems to evaluate the effects of model truncation. Simulations using a Linear Quadratic Regulator (LQR) design assuming full state feedback illustrate the effect of control spillover. Simulations of a system using output feedback illustrate the destabilizing effect of observation spillover. The simulations reveal that the system with passive damping is less susceptible to these effects than the untreated case.

Author

**N89-26574\*** Massachusetts Inst. of Tech., Cambridge.

**A VIRTUAL MANIPULATOR MODEL FOR SPACE ROBOTIC SYSTEMS**

S. DUBOWSKY and Z. VAFA In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 3 p 342-344 1 Jul. 1987 (Contract NAG1-489)

Avail: NTIS HC A18/MF A03 CSCL 13/9

Future robotic manipulators carried by a spacecraft will be required to perform complex tasks in space, like repairing satellites. Such applications of robotic manipulators will encounter a number of kinematic, dynamic and control problems due to the dynamic coupling between the manipulators and the spacecraft. A new analytical modeling method for studying the kinematics and dynamics of manipulators in space is presented. The problem is treated by introducing the concept of a Virtual Manipulator (VM). The kinematic and dynamic motions of the manipulator, vehicle and payload, can be described relatively easily in terms of the Virtual Manipulator movements, which have a fixed base in inertial space at a point called a Virtual Ground. It is anticipated that the approach described here will aid in the design and development of future space manipulator systems.

Author

**N89-26577\*** Ametek, Inc., Santa Barbara, CA.

**CONCEPT DEVELOPMENT OF A TENDON ARM MANIPULATOR AND ANTHROPOMORPHIC ROBOTIC HAND**

C. T. TOLMAN In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telerobotics, Volume 3 p 365-371 1 Jul. 1987

Avail: NTIS HC A18/MF A03 CSCL 13/9

AMETEK/ORED inhouse research and development efforts leading toward a next-generation robotic manipulator arm and end-effector technology is summarized. Manipulator arm development has been directed toward a multiple-degree-of-freedom, flexible, tendon-driven concept referred to here as a Tendon Arm Manipulator (TAM). End-effector development has been directed toward a three-fingered, dextrous, tendon-driven, anthropomorphic configuration which is referred to as an Anthropomorphic Robotic Hand (ARH). Key technology issues are identified for both concepts.

Author

**N89-26578\*** National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, MD.

**THE 1989 GODDARD CONFERENCE ON SPACE APPLICATIONS OF ARTIFICIAL INTELLIGENCE**

JAMES RASH, ed. Washington Apr. 1989 385 p Conference

held in Greenbelt, MD, 16-17 May 1989

(NASA-CP-3033; REF T-89B00099; NAS 1.55:3033) Avail: NTIS HC A17/MF A03 CSCL 09/2

The following topics are addressed: mission operations support; planning and scheduling; fault isolation/diagnosis; image processing and machine vision; data management; and modeling and simulation.

**N89-26600\*** Martin Marietta Corp., Denver, CO. Information and Communications Systems.

**A RAPID PROTOTYPING/ARTIFICIAL INTELLIGENCE APPROACH TO SPACE STATION-ERA INFORMATION MANAGEMENT AND ACCESS**

RICHARD S. CARNAHAN, JR., STEPHEN M. COREY, and JOHN B. SNOW In NASA, Goddard Space Flight Center, The 1989 Goddard Conference on Space Applications of Artificial Intelligence p 265-279 Apr. 1989

Avail: NTIS HC A17/MF A03 CSCL 09/2

Applications of rapid prototyping and Artificial Intelligence techniques to problems associated with Space Station-era information management systems are described. In particular, the work is centered on issues related to: (1) intelligent man-machine interfaces applied to scientific data user support, and (2) the requirement that intelligent information management systems (IIMS) be able to efficiently process metadata updates concerning types of data handled. The advanced IIMS represents functional capabilities driven almost entirely by the needs of potential users. Space Station-era scientific data projected to be generated is likely to be significantly greater than data currently processed and analyzed. Information about scientific data must be presented clearly, concisely, and with support features to allow users at all levels of expertise efficient and cost-effective data access. Additionally, mechanisms for allowing more efficient IIMS metadata update processes must be addressed. The work reported covers the following IIMS design aspects: IIMS data and metadata modeling, including the automatic updating of IIMS-contained metadata, IIMS user-system interface considerations, including significant problems associated with remote access, user profiles, and on-line tutorial capabilities, and development of an IIMS query and browse facility, including the capability to deal with spatial information. A working prototype has been developed and is being enhanced.

Author

**N89-26775\*** Research Inst. for Advanced Computer Science, Moffett Field, CA.

**TELESCIENCE TESTBEDDING: AN IMPLEMENTATION APPROACH**

BARRY M. LEINER and JAMES R. WEISS (National Aeronautics and Space Administration, Washington, DC.) Feb. 1988 13 p (Contract NASW-4234)

(NASA-CR-185429; NAS 1.26:185429; RIACS-TR-88.2) Avail: NTIS HC A03/MF A01 CSCL 05/2

Telepresence is the term used to describe a concept being developed by NASA's Office of Space Science and Applications (OSSA) under the Science and Applications Information System (SAIS) Program. This concept focuses on the development of an ability for all OSSA users to be remotely interactive with all provided information system services for the Space Station era. This concept includes access to services provided by both flight and ground components of the system and emphasizes the accommodation of users from their home institutions. Key to the development of the telepresence capability is an implementation approach called rapid-prototype testbedding. This testbedding is used to validate the concept and test the applicability of emerging technologies and operational methodologies. Testbedding will be used to first determine the feasibility of an idea and then the applicability to real science usage. Once a concept is deemed viable, it will be integrated into the operational system for real time support. It is believed that this approach will greatly decrease the expense of implementing the eventual system and will enhance the resultant capabilities of the delivered system.

Author

**N89-27204\*** Rockwell International Corp., Canoga Park, CA. Rockwell Div.

**OTV TURBOPUMP CONDITION MONITORING, TASK E.5**

Final Report, Oct. 1988 - Sep. 1989

PAUL T. COLEMAN and J. J. COLLINS Aug. 1989 27 p

(Contract NAS3-23773)

(NASA-CR-182274; NAS 1.26:182274; RI/RD89-214-TASK-E.5)

Avail: NTIS HC A03/MF A01 CSCL 14/4

Recent work has been carried out on development of isotope wear analysis and optical and eddy current technologies to provide bearing wear measurements and real time monitoring of shaft speed, shaft axial displacement and shaft orbit of the Orbit Transfer Vehicle hydrostatic bearing tester. Results show shaft axial displacement can be optically measured (at the same time as shaft orbital motion and speed) to within 0.3 mils by two fiberoptic deflectometers. Evaluation of eddy current probes showed that, in addition to measuring shaft orbital motion, they can be used to measure shaft speed without having to machine grooves on the shaft surface as is the usual practice for turbomachinery. The interim results of this condition monitoring effort are presented.

Author

**N89-29992\*** Martin Marietta Corp., Denver, CO. Dept. of Advanced Automation Technology.

**KEY TECHNOLOGY ISSUES FOR SPACE ROBOTIC SYSTEMS**

ROGER T. SCHAPPELL 1987 18 p Presented at the 1987 Conference on Space Applications of Artificial Intelligence (AI) and Robotics, Greenbelt, MD, 13-14 May 1987

(NASA-TM-101872; NAS 1.15:101872) Avail: NTIS HC A03/MF

A01 CSCL 09/2

Robotics has become a key technology consideration for the Space Station project to enable enhanced crew productivity and to maximize safety. There are many robotic functions currently being studied, including Space Station assembly, repair, and maintenance as well as satellite refurbishment, repair, and retrieval. Another area of concern is that of providing ground based experimenters with a natural interface that they might directly interact with their hardware onboard the Space Station or ancillary spacecraft. The state of the technology is such that the above functions are feasible; however, considerable development work is required for operation in this gravity-free vacuum environment. Furthermore, a program plan is evolving within NASA that will capitalize on recent government, university, and industrial robotics research and development (R and D) accomplishments. A brief summary is presented of the primary technology issues and physical examples are provided of the state of the technology for the initial operational capability (IOC) system as well as for the eventual final operational capability (FOC) Space Station.

Author

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### MATERIALS

Includes mechanical properties of materials, and descriptions and analyses of different structural materials, films, coatings, bonding materials and descriptions of the effects of natural and induced space environments.

**A89-33150\*** Minnesota Mining and Mfg. Co., Saint Paul. **DURABLE THIN FILM COATINGS FOR REFLECTORS USED IN LOW EARTH ORBIT**

DONALD J. MCCLURE (3M Corporate Research Process Technologies Laboratory, Saint Paul, MN) Society of Vacuum Coaters, Annual Technical Conference, 32nd, Saint Louis, MO, Apr. 24-28, 1989, Paper. 5 p. refs

(Contract NAS3-25075)

This paper discusses the properties of thin film coatings used to provide a durable reflective surface for solar concentrators used in the solar dynamic system designed for the Space Station. The material system to be used consists of an adhesion promotion

layer, a silver reflective layer, and a protective layer of aluminum oxide and silicon dioxide. The performance characteristics of this system are described and compared to those of several alternative systems which use aluminum as the reflective layer. I.S.

**A89-35148**

**THE EFFECT OF TEMPERATURE ON THE MATERIAL DAMPING OF GRAPHITE/EPOXY COMPOSITES IN A SIMULATED SPACE ENVIRONMENT**

G. T. SPIRBAK (USAF, Cape Kennedy, FL) and J. R. VINSON (Delaware, University, Newark) IN: Recent advances in the macro- and micro-mechanics of composite materials structures; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 189-192. refs

Copyright  
Experimental techniques for measuring the material damping characteristics of CFRPs under simulated space conditions are described and demonstrated. Beam specimens of (0 deg)12 and (90 deg)12 AS4/3501-6 laminates are suspended at the nodes in a chamber filled with air at temperatures -65, 0, 70, 150, and 225 F and slightly excited with a modally tuned impulse hammer; the resulting vibration signals are monitored with a low-mass shear-type accelerometer bonded to the specimen. The temperature dependence of the damping ratio in a space environment is then determined by subtracting out the effects of atmospheric damping; the results are presented in graphs. T.K.

**A89-35312**

**MATERIALS STABILITY AND ENVIRONMENTAL DEGRADATION; PROCEEDINGS OF THE SYMPOSIUM, RENO, NV, APR. 5-7, 1988**

AARON BARKATT, ED. (Catholic University of America, Washington, DC), ELLIS D. VERINK, JR., ED. (Florida, University, Gainesville), and LESLIE R. SMITH, ED. (NIST, Gaithersburg, MD) Symposium sponsored by the Materials Research Society, DARPA, and USAF., Pittsburgh, PA, Materials Research Society (MRS Symposium Proceedings, Volume 125), 1988, 439 p. For individual items see A89-35313 to A89-35325.

(Contract AF-AFOSR-85-0355)

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Topics discussed in these proceedings are on the composites for critical applications, metals and alloys, environmental effects on glass, environmental cracking, radiation effects, coatings and surface modification, and the deterioration of natural, ancient, and modern glass. Papers are presented on the response of carbon-carbon composites to challenging environments, chemical interactions in ceramic and carbon-carbon composites, materials for rocket engine applications, the prediction of glass durability as a function of environmental conditions, and an empirical model for environmental damage at the crack tip. Attention is also given to electron interaction with alkali chromium fluorides in the high-resolution electron microscope, configured semiconductor/insulator coatings for corrosion prevention, experimental hydration studies of natural and synthetic glasses, and linear free-energy relationships in glass corrosion. I.S.

**A89-35314\*** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**RESPONSE OF CARBON-CARBON COMPOSITES TO CHALLENGING ENVIRONMENTS**

HOWARD G. MAAHS, CRAIG W. OHLHORST, DAVID M. BARRETT, PHILIP O. RANSONE, and J. WAYNE SAWYER (NASA, Langley Research Center, Hampton, VA) IN: Materials stability and environmental degradation; Proceedings of the Symposium, Reno, NV, Apr. 5-7, 1988. Pittsburgh, PA, Materials Research Society, 1988, p. 15-30. refs

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This paper presents results from material performance evaluations of oxidation-resistant carbon-carbon composites intended for multiuse aerospace applications, which cover the effects of the following environmental parameters: the oxidizing nature of the environments (including both high and low oxygen



partial pressures), high temperatures, moisture, cyclic temperature service, and foreign-object impact. Results are presented for the carbon-carbon material currently in use as the thermal-protection-system material on Space Shuttle, as well as for newer and more advanced structural forms of carbon-carbon composites. I.S.

#### A89-35315

##### ADVANCED METAL MATRIX COMPOSITES

C. ROBERT CROWE (U.S. Navy, Naval Research Laboratory, Washington, DC) IN: Materials stability and environmental degradation; Proceedings of the Symposium, Reno, NV, Apr. 5-7, 1988. Pittsburgh, PA, Materials Research Society, 1988, p. 31-43. refs

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Advanced metal matrix composites are emerging as materials of construction for high performance aerospace applications. The thrust is to develop high specific strength and high specific modulus ultra-lightweight composites using Al or Mg as matrix materials for space structure applications, and for higher temperature applications, to develop materials using various aluminides as matrix materials. This paper presents an overview of the methodology used to develop advanced MMCs and discusses the problems and limitations faced in achieving the composite materials development goals. Author

A89-35316\* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

##### OXIDATION AND PROTECTION OF FIBERGLASS-EPOXY COMPOSITE MASTS FOR PHOTOVOLTAIC ARRAYS IN THE LOW EARTH ORBITAL ENVIRONMENT

SHARON K. RUTLEDGE, MICHAEL L. CIANCONE (NASA, Lewis Research Center, Cleveland, OH), PHILLIP E. PAULSEN, and JOYCE A. BRADY (Cleveland State University, OH) IN: Materials stability and environmental degradation; Proceedings of the Symposium, Reno, NV, Apr. 5-7, 1988. Pittsburgh, PA, Materials Research Society, 1988, p. 45-52. refs

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The extent of degradation of fiberglass-epoxy composite masts of the Space Station solar array panel, when these are exposed to atomic oxygen environment of the low-earth orbit, was investigated in ground testing of fiberglass-epoxy composites in an RF plasma asher. In addition, several methods of protecting the composite structures were evaluated, including an aluminum braid covering, an In-Sn eutectic, and a silicone based paint. It was found that, during exposure, the epoxy at the surface of the composite was oxidized, exposing individual glass fibers which could easily be removed. The results of mass measurements and SEM examination carried out after thermal cycling and flexing of exposed composite samples indicated that coatings such as In-Sn eutectic may provide adequate protection by containing the glass fibers, even though mass loss still occurs. I.S.

#### A89-37909

##### THERMOPLASTICS FOR SPACE

J. A. BARNES and F. N. COGSWELL (Imperial Chemical Industries, PLC, Materials Research Center, Wilton, England) SAMPE Quarterly (ISSN 0036-0821), vol. 20, April 1989, p. 22-27. refs

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It is shown that carbon fiber reinforced PEEK exhibits a number of characteristics which suggest that the material is a good candidate for use in the space environment. A new 'space' tailored PEEK-based composite is described, and some interesting aspects of performance are discussed. It is concluded that both materials have potential for use in near and deep space, and that many of the advantages conferred by the use of PEEK with high strength carbon fibers may carry over to the pitch-reinforced system. Author

#### A89-39832#

##### CARBON-FIBER-REINFORCED CARBON (CFC) FOR HIGH-TEMPERATURE STRUCTURAL APPLICATIONS [KOHLENSTOFFASERVERSTAERKTER KOHLENSTOFF /CFC/ FUER STRUKTURELLE HOCHTEMPERATUR /HT/ ANWENDUNGEN]

H. LEIS, R. MEISTRING, G. DIETRICH, and A. GESSLER (Messerschmitt-Boelkow-Blohm GmbH, Ottobrunn, Federal Republic of Germany) Symposium ueber Materialforschung, Hamm, Federal Republic of Germany, Sept. 12-14, 1988, Paper. 20 p. In German.

(Contract BMFT-03-M-1019)

(MBB-Z-0220-88-PUB)

The effects of preparation and processing parameters on the high-temperature characteristics of carbon-matrix CFRPs are discussed, summarizing preliminary results from a joint program integrating basic research, manufacturing technology, and engineering design. The focus is on materials being developed in the FRG for future space applications. Consideration is given to the development of effective oxidation protection, quality and efficiency factors in the fabrication process, the measurement and compilation of material property data for use by designers, the identification of effective NDE methods, and in-service testing of model components. Diagrams of manufacturing processes, graphs of test data, and micrographs of typical composites are provided. T.K.

#### A89-41321

##### FIBRE COMPOSITES IN SATELLITES

A. SCHEDLER (Messerschmitt-Boelkow-Blohm GmbH, Ottobrunn, Federal Republic of Germany) Cryogenics (ISSN 0011-2275), vol. 28, April 1988, p. 220-223.

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Fiber-reinforced composites are applicable to spacecraft structural components in the 4-450 K range, where metallic components cannot furnish the requisite weight, stiffness, strength, thermal expansion, thermal conductivity, and electrical conductivity. An account is presently given of carbon fiber-reinforced composite structures for cryogenic vessel elements and solar arrays in Intelsat 5 and 6, Exosat, the Space Shuttle Pallet Satellite, and the IR Space Observatory. Attention is given to the thermal and structural consequences of the anisotropic nature of these composite structures. O.C.

#### A89-42983

##### GRAPHITE-EPOXY LAMINATES WITH ALMOST NULL COEFFICIENT OF THERMAL EXPANSION UNDER A WIDE RANGE OF TEMPERATURE

TAKASHI ISHIKAWA, HISAO FUKUNAGA, and KOH-ICHI ONO (National Aerospace Laboratory, Chofu, Japan) Journal of Materials Science (ISSN 0022-2461), vol. 24, June 1989, p. 2011-2017. refs

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A lamination tailoring technique is proposed in order to control a coefficient of thermal expansion of graphite-epoxy composites in a principal direction. This technique consists of two concepts of the thermoelastic invariants and the lamination parameters. The expansion free condition yields to a parabola in the feasible region of the lamination parameters. The calculated curves for a wide range of temperatures intersect almost at a point. A laminate with the lay-up construction corresponding to this point will exhibit an approximately null coefficient of thermal expansion in one direction in that temperature range. Some preliminary experimental results indicate that the present procedure is possible and promising. The tailored material will be appropriate for space station structure. Author

#### A89-45766

##### RESPONSE OF ADVANCED COMPOSITE SPACE MATERIALS TO THERMAL CYCLING

PIYUSH K. DUTTA, JOHN KALAFUT, DENNIS FARRELL (U.S. Army, Cold Regions Research and Engineering Laboratory, Hanover, NH), and HAROLD W. LORD (Michigan Technological

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University, Houghton, MI) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 506-517. refs  
Copyright

The paper discusses the results of an experimental study of thermal cycling and microcrack damage and their effect on the stiffness and strengths of some polymer matrix composite materials. This study grew out of the concern that thermal stresses induced by the first cooldown process of low-temperature thermal cycling lead to damage in composites that in subsequent cycles can grow to cause degradation of mechanical behavior. Effects due to 10 low-temperature thermal-cycles on the tensile strength and elastic properties of unidirectional graphite-epoxy composites were determined. There was an apparent increase in strength for the fiber-dominated mode of failure (0 deg specimens) and a degradation in strength for the matrix-dominated modes of failure (45 and 90 deg specimens) due to thermal cycling for the unidirectional laminates. B.J.

### A89-45927

#### SPACE AGE METALS TECHNOLOGY; PROCEEDINGS OF THE SECOND INTERNATIONAL SAMPE METALS AND METALS PROCESSING CONFERENCE, DAYTON, OH, AUG. 2-4, 1988

F. H. FROES, ED. (USAF, Materials Laboratory, Wright-Patterson AFB, OH) and RAY A. CULL, ED. Conference sponsored by SAMPE, Covina, CA, Society for the Advancement of Material and Process Engineering (International SAMPE Metals and Metals Processing Conference Series, Volume 2), 1988, 542 p. For individual items see A89-45928 to A89-45959.  
Copyright

The present conference discusses advancements in Ti alloy casting methods, NiAl-based alloys for high temperature applications, electron-beam cold hearth melting of metals, Al-Li alloys for fighter aircraft applications, mechanically-alloyed high-modulus/elevated temperature Al-Ti alloys, the stress-induced hot corrosion of Rene 90, the high temperature oxidation behavior of Ti3Al alloys, and Ti requirements for current and future military gas turbine engines. Also discussed are the fatigue behavior of P/M Ti-6Al-4V, hydrogen in advanced aerospace materials, beryllides for very high temperature service, rapidly solidified P/M Al-Fe-Ce alloys, advanced Mg alloys for aerospace applications, adaptive gas tungsten arc-welding, development trends in electrodeposition, the fractography of titanium aluminide metal-matrix composites, and ingot-metallurgy metal-matrix composites. O.C.

### A89-46983#

#### ADVANCES IN COMPOSITE FIBER/METAL PRESSURE VESSEL TECHNOLOGY

EDGAR E. MORRIS (Structural Composites Industries, Pomona, CA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 11 p.  
(AIAA PAPER 89-2643) Copyright

The technology exists today to design and produce lightweight, high-reliability composite fiber/metal pressure vessels for many commercial and aerospace applications. A broad range of tank efficiencies (weights) is available depending on specific construction materials selected and cost considerations. Reduction of weight continues to be the dominant factor in design and materials selection for many new aerospace applications. The weight saving advantages to be achieved in pressure vessels by utilizing the latest developments in advanced carbon fiber materials technology has been demonstrated. Using the carbon fiber composite for weight reduction with commercial seamless aluminum liner technology provides both high performance and cost economy. Author

A89-46984\*# McDonnell-Douglas Astronautics Co., Huntington Beach, CA.

#### SUSTAINED LOAD BEHAVIOR OF GRAPHITE/EPOXY METAL-LINED PRESSURE VESSELS FOR LONG-LIFE SPACE APPLICATIONS

H. W. BABEL, B. D. VICKERS (McDonnell Douglas Space Systems Co., Huntington Beach, CA), and D. A. THOMAS (NASA, Johnson Space Center, Houston, TX) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 9 p. refs  
(AIAA PAPER 89-2644) Copyright

Tests were performed on candidate graphite yarns for the overwraps to be used on the Space Station Freedom's pressure vessels. The objective was to determine the performance and ranking of these overwraps to ensure that sustained loads would not be a problem during their 30-yr life in space. Tests were conducted at high stress levels for short time periods on subscale composite bottles. The average delivered fiber stresses were determined from the measured burst pressures via SCI analysis that accounts for both geometry and the properties of the resin and yarn. K.K.

### A89-51102

#### BUILDING OF SPACE STATIONS - WHICH MATERIALS?

ERIK SLACHMUYLDERS (ESA, Noordwijk, Netherlands) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings. Toulouse, France, Cepadues Editions, 1989, p. 23-33.  
Copyright

The selection of the materials to be used in the Space Station is examined with emphasis on the attached pressurized module (APM), and the man-tended free flyer (MFF) elements. The materials/processes requirements for the Space Station are broken down into two main classes: structural/functional integrity and compatibility with the manned environment. (Pre)launch environment, orbital lifetime (30 years), and in-orbit operations are the main factors determining the long term structural and functional integrity of the Space Station elements. The choice of materials in the area of manned environment is related to existing standards modification, radiation protection, biological compatibility, decontamination and (re)sterilization, fungus, and unexpected events. C.E.

### A89-51106

#### COMPOSITE MATERIAL OXIDATION IN OXYGEN MICROWAVE-INDUCED PLASMA

J. M. GUILLERME, J. L. BONARDET, A. M. DIAMY, J. C. LEGRAND, J. FRAISSARD (Paris VI, Université, France) et al. IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings. Toulouse, France, Cepadues Editions, 1989, p. 87-94. refs  
Copyright

Oxidation resistance of composite materials which can be used to protect shuttles is studied in oxygen microwave-induced plasmas. These plasmas contain the same energetic species (electrons, ions, radicals, excited atoms or molecules) as those produced by the shock wave resulting from the reentry into the atmosphere. Kinetic behavior of the material is studied by gravimetry, and surface characteristic modifications are analyzed by BET krypton isotherms at 77 K and ESCA. Author

A89-51108\* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

#### SPACE STATION MATERIAL LIFE CONSIDERATIONS

L. J. LEGER, M. FOWLER (NASA, Johnson Space Center, Houston, TX), T. A. CRUSE, and C. H. PARR (Southwest Research Institute, San Antonio, TX) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings. Toulouse, France, Cepadues Editions, 1989, p. 111-120. refs  
(Contract NCC9-17)  
Copyright

Space Station life requirements for the overall system are currently stated as thirty years of constant space operation. This aspect of constant in-space operation and long life brings in environmental compatibility requirements which place severe new constraints on material selection. Activities within the United States are currently addressing many of these material selection issues

including development of coatings and other space-durable materials, material selection methodology, and life certification methodology. A summary of these activities is presented. Author

**A89-51111**

**MATERIALS RELATED INFLUENCE ON MAINTENANCE AND REPAIR OF COLUMBUS ELEMENTS**

HENDRIK WESSELS (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings. Toulouse, France, Cepadues Editions, 1989, p. 145-157.

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The material versus maintainability and repair aspects of the Columbus space segment are presented. Materials selection becomes a very important system aspect with very strong influence on reliability, maintainability, operability of the Attached Pressurized Module (APM), the Man Tended Free Flyer (MTFF), and the Polar Platform (PPF) of the Columbus spacecraft. Some examples illustrate the major maintainability-related selection criteria and their relation to materials characteristics such as microbiological contamination, structural restorability, inspection methods, and material long-term behavior. C.E.

**A89-51112**

**COLUMBUS MATERIALS' LONG TERM OUTGASSING**

HANS-J. STEPHAN (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings. Toulouse, France, Cepadues Editions, 1989, p. 159-170.

Copyright

The combination of a 30 years life-time requirement for COLUMBUS together with the need for on-orbit maintenance, exchange, and repair added a new dimension to the materials requirements. This paper introduces the potential application of the Residence Time Model for long term outgassing prediction and relates those values to mechanical properties changes of nonmetallic materials used in a vacuum environment. The current status of this area of the Columbus project and future perspectives are presented. Author

**A89-51113**

**LIFE PREDICTION OF COLUMBUS VIEWPORT GLASS PANES**

D. ALWES (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany), P. O. REDGRAVE, and R. HAYWARD (Triplex Aircraft and Special Products, Ltd., Birmingham, England) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings. Toulouse, France, Cepadues Editions, 1989, p. 171-182.

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The viewport glass panes as critical items of the Columbus Space Station shall have a lifetime of 30 years including maintenance, refurbishment and replacement capability. A viewport concept has been developed, which shall allow for the glass pane exchange inside the Pressurized Module. The glass pane configuration of this concept has been investigated with special attention to its hypervelocity impact behavior and its radiation resistance, which are the most relevant factors for the lifetime in orbit. Author

**A89-51115**

**IN-ORBIT MATERIAL TESTING**

G. G. REIBALDI (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings. Toulouse, France, Cepadues Editions, 1989, p. 203-214.

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Present and future plans for in-orbit material testing in the framework of the In-orbit Technology Demonstration Program (TDP) are discussed. In the first phase the TDP includes in-flight contamination and atomic oxygen experiments, single event upset

in electronics, and radiation monitoring. In subsequent program phases, large complements of equipment for, e.g., robotics, in-orbit fuel-transfer tests, and fluid dynamics, will be flight-tested. The TDP follow-up phases will concentrate on continuation of experiments of common interest, support to the development and utilization phases of new programs, and in-orbit performance testing for new technologies. Space environmental interaction remains an important aspect of the program. Experiments on solar array plasma interaction, and atmosphere material interaction are being designed. The in-orbit TDP will try to provide a low cost access to orbit for testing new materials in space using several carriers. C.E.

**A89-51148**

**EMERGENCY LUBRICATION BY CVD AND PVD COATINGS**

H. E. HINTERMANN, H. BOVING, W. HANNI, and C. MENOUD (Centre Suisse d'Electronique et de Microtechnique, S.A., Neuchâtel, Switzerland) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings. Toulouse, France, Cepadues Editions, 1989, p. 729-739. refs

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TiC coatings are shown to have excellent friction lowering and wear lowering properties, and to provide a significant improvement in the tribological and antiwelding (or 'emergency lubricating') behavior of conventional steel bearings operated at extreme conditions. The highly polished CVD and PVD deposited TiC coatings have thicknesses of about one to several microns. It is found that further improvement can be obtained by the application of an additional thin film of about one or several tenths of a micron of MoS<sub>2</sub> on top of the polished TiC coating. Single (TiC) or double (TiC/MoS<sub>2</sub>) coated high precision bearings have been tested for space applications. R.R.

**A89-51281#**

**ADVANCES IN THIN, SOLID FILM LUBRICATION FOR SPACE APPLICATIONS**

E. W. ROBERTS (U.K. Atomic Energy Authority, European Space Tribology Laboratory, Risley, England) IN: National Conference on Industrial Tribology, Trivandrum, India, Jan. 19, 20, 1989, Proceedings. Volume 1. Trivandrum, India, Vikram Sarabhai Space Centre, 1989, p. VII-1.1 to VII-1.7. refs

This paper sets out to discuss advances in thin, solid film lubrication for space applications. Such advances, in addition to those made in the technology of film fabrication, include improvements in the understanding of film behavior in terms of contact mechanics, interface chemistry, film structure and composition. By way of illustration the in vacuo tribological properties of thin films of lead and molybdenum disulphide formed by PVD (physical vapor deposition) processes are reviewed. Current research aimed at improving the tribological performance, in particular the endurance of such films, by means of surface and interface modifications, is discussed. Author

**A89-54886\*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

**ISSUES RELATED TO TESTING OF SPACE STATION MATERIALS**

M. FOWLER, L. LEGER (NASA, Johnson Space Center, Houston, TX), and T. CRUSE (Southwest Research Institute, San Antonio, TX) IN: Aerospace Testing Seminar, 11th, Manhattan Beach, CA, Oct. 11-13, 1988, Proceedings. Mount Prospect, IL, Institute of Environmental Sciences, 1988, p. 237-242. refs

Issues pertaining to the long life of Space Station materials and to the test methodology for the certification of these materials are presented. Consideration is given to atomic oxygen degradation, debris and micrometeoroid damage, and thermal cycling. It is noted that the integration of the combined effects of all of these phenomena is highly important as they cannot be viewed as separate issues. K.K.

**N89-20167** Utah State Univ., Logan.

**ABLATION OF MATERIALS IN THE LOW EARTH ORBITAL**



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### ENVIRONMENT Ph.D. Thesis

RUSSEL ROGER LAHER 1987 176 p

Avail: Univ. Microfilms Order No. DA8823639

The ablation of external surfaces of a spacecraft in orbit by gas molecules in the atmosphere is investigated. A near-earth orbiting spacecraft moves through the atmosphere at about 8 km/sec. This relative speed allows gas molecules to impinge upon spacecraft surfaces with energies in the range of 5 to 10 eV, a sufficient amount, in many cases, to ablate molecules of surface material at an appreciable rate, as demonstrated from analyses of materials flown on Space Shuttle missions STS-1 through STS-5, STS-8 and STS-41G, and the results of the analyses on materials retrieved from the Solar Maximum Mission satellite is given. The physical parameters of both the atmosphere and the surface materials that control this process, and possible mechanisms for surface ablation are examined. Based upon these considerations, two different ablation models, one for polycrystalline materials and one for amorphous materials are formulated for use in computing ablation rates of materials exposed to the low earth orbital environment. Using a standard atmosphere with altitude profiles of temperatures and concentrations for both neutral and ionic species, maximum ablation rates as a function of satellite altitude in the 100 to 1000 km range are estimated for elementary polycrystalline solids from sputtering data obtained from laboratory measurements. Dissert. Abstr.

### N89-21821\*# Boeing Aerospace Co., Seattle, WA.

#### SPACE STATION PROTECTIVE COATING DEVELOPMENT

##### Final Report

H. G. PIPPIN and S. G. HILL Jan. 1989 304 p

(Contract NAS8-36586)

(NASA-CR-183585; NAS 1.26:183585) Avail: NTIS HC A14/MF A02 CSCL 22/2

A generic list of Space Station surfaces and candidate material types is provided. Environmental exposures and performance requirements for the different Space Station surfaces are listed. Coating materials and the processing required to produce a viable system, and appropriate environmental simulation test facilities are being developed. Mass loss data from the original version of the atomic oxygen test chamber and the improved facility; additional environmental exposures performed on candidate materials; and materials properties measurements on candidate coatings to determine the effects of the exposures are discussed. Methodologies of production, and coating materials, used to produce the large scale demonstration articles are described. The electronic data base developed for the contract is also described. The test chamber to be used for exposure of materials to atomic oxygen was built. B.G.

### N89-21882 Centre National d'Etudes Spatiales, Toulouse (France).

#### MATERIALS FOR SPACE USE (MATERIALS ASSESSMENT)

##### [LES MATERIAUX A USAGE SPATIAL (EXPERTISE MATERIAUX)]

JACQUELINE PRADES *In its* Quality, Components and Technological Analysis p 1101-1157 Aug. 1988 In FRENCH; ENGLISH summary

Copyright Avail: CEPADUES-Editions, 111 Rue Nicolas-Vauquelin, 31100 Toulouse, France

A definition of materials concerned by quality assurance is given, recalling the particularities of the space industry. The characteristics, applications, and foreseen development of the basic materials meeting aerospace requirements are shown. Potential defects and manufacturing difficulties are examined. Examples are taken in metallic and composite industries. General principles of testing procedures are presented. A list of elements of prime importance for quality assurance of materials is included. ESA

### N89-23533\*# Oak Ridge National Lab., TN.

#### SURFACE TREATMENT USING METAL FOIL LINER

RAY GARVEY *In* NASA, Langley Research Center, NASA/SDIO Space Environmental Effects on Materials Workshop, Part 1 p 87-99

May 1989

Avail: NTIS HC A16/MF A02 CSCL 11/4

A metal foil liner can be used to seal large area surfaces. Characteristics of the two-layer foil liner are discussed. Micrographs for foil-to-foil, foil-to-composite, visible seams, and hidden seams are examined. Author

### N89-23535\*# Naval Research Lab., Washington, DC.

#### SOME EXAMPLES OF THE DEGRADATION OF PROPERTIES OF MATERIALS IN SPACE

FREDERICK E. BETZ and JOSEPH A. HAUSER *In* NASA, Langley Research Center, NASA/SDIO Space Environmental Effects on Materials Workshop, Part 1 p 109-121 May 1989

Avail: NTIS HC A16/MF A02 CSCL 11/7

The space environment effects on the silver teflon covering (solar panels) of two SOLRAD SATELLITES AND NTS-Z are examined to analyze the design requirements for the Shuttle Launch Dispenser (SLD). Author

### N89-23547\*# National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

#### NASA/SDIO SPACE ENVIRONMENTAL EFFECTS ON MATERIALS WORKSHOP, PART 2

LOUIS A. TEICHMAN, comp. and BLAND A. STEIN, comp. Washington May 1989 253 p Workshop held in Hampton, VA, 28 Jun. - 1 Jul. 1988

(NASA-CP-3035-PT-2; L-16575-PT-2; NAS 1.55:3035-PT-2)

Avail: NTIS HC A12/MF A02 CSCL 11/7

The National Aeronautics and Space Administration (NASA) and the Strategic Defense Initiative Organization (SDIO) cosponsored a workshop on Space Environmental Effects on Materials. The joint workshop was designed to inform participants of the present state of knowledge regarding space environmental effects on materials and to identify knowledge gaps that prevent informed decisions on the best use of advanced materials in space for long duration NASA and SDIO missions. Establishing priorities for future ground based and space based materials research was a major goal of the workshop. The end product of the workshop was an assessment of the current state-of-the-art in space environmental effects on materials in order to develop a national plan for spaceflight experiments.

### N89-23552\*# National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

#### EFFECTS OF THERMAL CYCLING ON COMPOSITE MATERIALS FOR SPACE STRUCTURES

STEPHEN S. TOMPKINS *In its* NASA/SDIO Space Environmental Effects on Materials Workshop, Part 2 p 447-470 May 1989

Avail: NTIS HC A12/MF A02 CSCL 22/2

The effects of thermal cycling on the thermal and mechanical properties of composite materials that are candidates for space structures are briefly described. The results from a thermal analysis of the orbiting Space Station Freedom is used to define a typical thermal environment and the parameters that cause changes in the thermal history. The interactions of this environment with composite materials are shown and described. The effects of this interaction on the integrity as well as the properties of GR/thermoset, GR/thermoplastic, GR/metal and GR/glass composite materials are discussed. Emphasis is placed on the effects of the interaction that are critical to precision spacecraft. Finally, ground test methodology are briefly discussed. Author

### N89-23557\*# National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, TX.

#### ATOMIC OXYGEN

LUBERT J. LEGER and JAMES T. VISENTINE *In* NASA, Langley Research Center, NASA/SDIO Space Environmental Effects on Materials Workshop, Part 2 p 545-552 May 1989

Avail: NTIS HC A12/MF A02 CSCL 20/8

The effects of atomic oxygen (AO) on materials in aerospace environments are examined. Materials are categorized according to their susceptibility to AO. The degradation effects of AO are examined to determine which materials are most vulnerable.

Classes of spacecraft materials are listed and correlated with a performance category. The spacecraft orbits sensitive to AO interactions are also listed. Correlations are presented of AO effects on materials and of spacecraft glow effects. E.R.

**N89-23691#** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**UNDERCUTTING OF DEFECTS IN THIN FILM PROTECTIVE COATINGS ON POLYMER SURFACES EXPOSED TO ATOMIC OXYGEN**

SHARON K. RUTLEDGE and JUDITH A. MIHELIC (Cleveland State Univ., OH.) 1989 10 p. Presented at the 16th International Conference on Metallurgical Coatings, San Diego, CA, 17-21 Apr. 1988; sponsored by American Vacuum Society (NASA-TM-101986; E-4686; NAS 1.15:101986) Avail: NTIS HC A02/MF A01 CSCL 11/3

Protection for polymeric surfaces is needed to make them durable in the low Earth orbital environment, where oxidation by atomic oxygen is the predominant failure mechanism. Thin film coatings of oxides such as silicon dioxide are viable candidates to provide this protection, but concern has been voiced over the ability of these coatings to protect when defects are present in the coating due to surface anomalies occurring during the deposition process, handling, or micrometeoroid and debris bombardment in low Earth orbit. When a defected coating protecting a polymer substrate is exposed to atomic oxygen, the defect provides a pathway to the underlying polymer allowing oxidation and subsequent undercutting to occur. Defect undercutting was studied for sputter deposited coatings of silicon dioxide on polyimide Kapton. Preliminary results indicate that undercutting may be limited as long as the coating remains intact with the substrate. Therefore, coatings may not need to be defect free to give protection to the underlying surface. Author

**N89-25358#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Stuttgart (Germany, F.R.). Structures and Materials Dept.

**MATERIALS AND STRUCTURES FOR 2000 AND BEYOND: AN ATTEMPTED FORECAST**

CARL-JOCHEN WINTER and MARTIN MAILAENDER Feb. 1989 86 p. In GERMAN; ENGLISH summary (DFVLR-MITT-89-02; ISSN-0176-7739; ETN-89-94648; AD-B133639L) Avail: NTIS HC A05/MFA01; DFVLR, VB-PL-DO, Postfach 90 60 58, 5000 Cologne, Federal Republic of Germany, 51 deutsche marks

Developments in aerospace materials and structures, and research needed to meet the challenges imposed by these developments were discussed. ESA

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## INFORMATION AND DATA MANAGEMENT

Includes descriptions, requirements, and trade studies of different information and data system hardware and software, languages, architecture, processing and storage requirements for managing and monitoring of different systems and subsystems.

**A89-42613**

**DEDICATED SOFTWARE FOR PROCESSING AND COMPRESSION OF DATA OBTAINED WITH MKS-M SYSTEM [SPETSIAL'NOE MATEMATICHESKOE OBEPECHENIE DLIA OBRABOTKI I SZHATIYA INFORMATSII, REGISTRIRUEMOI S POMOSHCH'U APPARATURY MKS-M]**

V. V. BADAEV, V. N. VORONKOV, E. A. GAVRILOVA, I. M. MANSUROV, and V. D. MASLOV (AN SSSR, Institut Kosmicheskikh Issledovaniy, Moscow, USSR) Issledovanie Zemli iz Kosmosa (ISSN 0205-9614), Mar.-Apr. 1989, p. 95-103. In Russian. refs Copyright

The software for processing and compressing data obtained

by the MKS-M multichannel spectrometer on board Salyut-7 is described. It is shown that input data can be compressed in the temporal and spectral domains using the orthogonal transformation method, and the information-bearing data can be retrieved with no loss of accuracy, with an error of 5 percent. The compression factor that can be achieved is shown to range from 8 to 10. I.S.

**A89-43117#**

**ONBOARD DATA MANAGEMENT FOR SPACE STATION COLUMBUS [BORD-DATENVERWALTUNG IN DER RAUMSTATION COLUMBUS]**

FRANZ-JOSEF ROMBECK and ERICH WEH Domier Post (ISSN 0012-5563), no. 3, 1988, p. 36, 37. In German. Copyright

The design concept and current development status of the onboard data-management subsystem for Columbus are reviewed. The system architecture comprises assemblies for telemetry and command, data bases, document files, workstations, time distribution, interconnection, data management proper, and data processing. Particular attention is given to the data-base and document-file assemblies, which are described in detail and illustrated with block diagrams. The data-base assembly offers a usable capacity of 130 Mbytes, hot and cold redundancy, and fault tolerance; the document-file assembly represents a significant part of the Columbus man-machine interface, permitting flexible display and manipulation of crew information in the form of text, tables, graphics, drawings, and images. T.K.

**A89-48167#** Science Applications International Corp., New York, NY.

**ESTABLISHING A DATA BASE FOR AN AEROSPACE SYSTEMS MAINTAINABILITY ASSESSMENT**

JOSEPH R. FRAGOLA (Science Applications International Corp., New York) AIAA and NASA, Symposium on the Maintainability of Aerospace Systems, Anaheim, CA, July 26, 27, 1989. 11 p. Research supported by AIAA and NASA. refs (AIAA PAPER 89-5056) Copyright

The scope, goals, and objectives are examined of a joint NASA/AIAA effort to establish a quantitative base of reliability data for aerospace system maintenance which is the best available from current sources. The joint effort intends to assess where the current base of historical information is useful, to what it is applicable, and in what way it can be made available to the aerospace user community. The effort will identify areas where data are nonexistent, where and how data may be technically lacking, and what roadblocks might exist to the general availability of such data. The effort is also intended to identify recommended courses of action to be taken by the aerospace community in order to move toward the eventual development of a set of reliability data capable of meeting the expanded requirements of era of the Space Station Freedom. Insights which have been obtained during the course of the program implementation are highlighted. C.D.

**A89-53298#**

**GETTING A GRIP ON THE SOFTWARE**

BRUCE FRISCH Aerospace America (ISSN 0740-722X), vol. 27, Sept. 1989, p. 28, 29. Copyright

The proposed computer programming code for the operating systems of the Space Station Freedom is examined. A software support environment (SSE) is being developed to assist in the designing of the computer code. The SSE system is to be utilized for the design, integration, testing, and maintainability of the software. The software and materials of the SSE are described. The integration, development and production facilities for creating the Space Station's software are discussed. I.F.

**N89-20859#** General Accounting Office, Washington, DC.

**SPACE OPERATIONS: TESTING OF NASA'S TECHNICAL AND MANAGEMENT INFORMATION SYSTEM**

Mar. 1988 8 p (GAO/IMTEC-88-28) Avail: NTIS HC A02/MF A01

The status of the development of the National Aeronautics

## 12 INFORMATION AND DATA MANAGEMENT

and Space Administration's Technical and Management Information System (TMIS) is presented. TMIS is intended to support the design, development, and operation of the planned space station. The parameters involved in the development of TMIS are data base management, project management, document management, electronic mail, workstations, hardware, interfaces and networking. It is estimated that initial operating capability (IOC) will be available at all NASA Centers by June 1988. M.G.

**N89-22335\*** National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, AL.

### **ORBITAL MANEUVERING VEHICLE TELEOPERATION AND VIDEO DATA COMPRESSION**

STEVE JONES In NASA, Goddard Space Flight Center, Proceedings of the Scientific Data Compression Workshop p 99-117 Feb. 1989

Avail: NTIS HC A19/MF A03 CSCL 22/2

The Orbital Maneuvering Vehicle (OMV) and concepts of teleoperation and video data compression as applied to OMV design and operation are described. The OMV provides spacecraft delivery, retrieval, reboost, deboost and viewing services, with ground-control or Space Station operation, through autonomous navigation and pilot controlled maneuvers. Communications systems are comprised of S-band RF command, telemetry, and compressed video data links through the TDRSS and GSTDN networks. The control console video monitors display a monochrome image at an update rate of five frames per second. Depending upon the mode of operation selected by the pilot, the video resolution is either 255 x 244 pixels, or 510 x 244 pixels. Since practically all video image redundancy is removed by the compression process, the video reconstruction is particularly sensitive to data transmission bit errors. Concatenated Reed-Solomon and convolution coding are used with helical data interleaving for error detection and correction, and an error-containment process minimizes the propagation of error effects throughout the video image. Video sub-frame replacement is used, in the case of a non-correctable error or error burst, to minimize the visual impact to the pilot. Author

**N89-22342\*** Fairchild Weston Systems, Inc., Syosset, NY.  
**THE OMV DATA COMPRESSION SYSTEM SCIENCE DATA COMPRESSION WORKSHOP**

GARTON H. LEWIS, JR. In NASA, Goddard Space Flight Center, Proceedings of the Scientific Data Compression Workshop p 251-300 Feb. 1989

Avail: NTIS HC A19/MF A03 CSCL 05/2

The Video Compression Unit (VCU), Video Reconstruction Unit (VRU), theory and algorithms for implementation of Orbital Maneuvering Vehicle (OMV) source coding, docking mode, channel coding, error containment, and video tape preprocessed space imagery are presented in viewgraph format. B.G.

**N89-24379\*** Telespazio, S.p.A., Rome (Italy).

### **THE KEY ROLE OF DATA RELAY SYSTEM (DRS) IN THE COLUMBUS COMMUNICATIONS**

VICTOR SPEZIALE In ESA, International Symposium on Europe in Space: The Manned Space System p 403-407 Oct. 1988  
Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The contribution of the Data Relay System (DRS) to the Columbus program communication network is discussed. The DRS space segment and ground segment are described. User operations are outlined. The DRS is based on two geostationary satellites positioned so as to get the best compromise between the conflicting requirements of minimization of world coverage gaps and maximization of the area where data are broadcast. The DRS could also assist in orbit localization. ESA

**N89-24387\*** Selenia Spazio S.p.A., Rome (Italy).

### **THE COLUMBUS CREW COMMUNICATION SUBSYSTEM AND THE ON BOARD LOCAL AREA NETWORK**

A. MORANDO, A. FRANCA, M. MASCI, and GIU. MONTALTO In ESA, International Symposium on Europe in Space: The Manned

Space System p 551-563 Oct. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The Columbus local area network (LAN) and crew communication system is described. The architecture of the system consists of several independent network assemblies (including the onboard LAN, audio network, and video network) each dedicated to a particular type of data, and a gateway, called communication processor, supporting data exchange between onboard and ground. ESA

**N89-25773\*** Research Inst. for Advanced Computer Science, Moffett Field, CA.

### **PERFORMANCE ISSUES IN MANAGEMENT OF THE SPACE STATION INFORMATION SYSTEM**

MARJORY J. JOHNSON Sep. 1988 22 p Revised

(Contract N002-387)

(NASA-CR-185409; NAS 1.26:185409; RIACS-TR-88.22) Avail: NTIS HC A03/MF A01 CSCL 05/2

The onboard segment of the Space Station Information System (SSIS), called the Data Management System (DMS), will consist of a Fiber Distributed Data Interface (FDDI) token-ring network. The performance of the DMS in scenarios involving two kinds of network management is analyzed. In the first scenario, how the transmission of routine management messages impacts performance of the DMS is examined. In the second scenario, techniques for ensuring low latency of real-time control messages in an emergency are examined. Author

**N89-26450\*** Research Inst. for Advanced Computer Science, Moffett Field, CA.

### **COMPUTER NETWORKS FOR REMOTE LABORATORIES IN PHYSICS AND ENGINEERING**

SCOTT STARKS, DAVID ELIZANDRO, BARRY M. LEINER, and MICHAEL WISKERCHEN (Stanford Univ., CA.) Apr. 1988 10 p Presented at the 1988 ASEE Southeastern Section Conference (Contract NASW-4234)

(NASA-CR-185403; NAS 1.26:185403; RIACS-TR-88.13) Avail: NTIS HC A03/MF A01 CSCL 09/2

This paper addresses a relatively new approach to scientific research, telescience, which is the conduct of scientific operations in locations remote from the site of central experimental activity. A testbed based on the concepts of telescience is being developed to ultimately enable scientific researchers on earth to conduct experiments onboard the Space Station. This system along with background materials are discussed. Author

**N89-26475\*** Michigan Univ., Ann Arbor.

### **AN APPROACH TO DISTRIBUTED EXECUTION OF ADA PROGRAMS**

R. A. VOLZ, P. KRISHNAN, and R. THERIAULT In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Workshop on Space Telemetry, Volume 1 p 187-197 1 Jul. 1987  
Avail: NTIS HC A16/MF A03 CSCL 09/2

Intelligent control of the Space Station will require the coordinated execution of computer programs across a substantial number of computing elements. It will be important to develop large subsets of these programs in the form of a single program which executes in a distributed fashion across a number of processors. A translation strategy for distributed execution of Ada programs in which library packages and subprograms may be distributed is described. A preliminary version of the translator is operational. Simple data objects (no records or arrays as yet), subprograms, and static tasks may be referenced remotely. Author

**N89-26584\*** Maryland Univ., College Park. Dept. of Computer Science.

### **PARALLEL PLAN EXECUTION WITH SELF-PROCESSING NETWORKS**

C. LYNNE DAUTRECHY and JAMES A. REGGIA In NASA, Goddard Space Flight Center, The 1989 Goddard Conference on



Space Applications of Artificial Intelligence p 61-73 Apr. 1989  
(Contract NAG1-885; NSF IRI-84-51430)  
Avail: NTIS HC A17/MF A03 CSCL 09/2

A critical issue for space operations is how to develop and apply advanced automation techniques to reduce the cost and complexity of working in space. In this context, it is important to examine how recent advances in self-processing networks can be applied for planning and scheduling tasks. For this reason, the feasibility of applying self-processing network models to a variety of planning and control problems relevant to spacecraft activities is being explored. Goals are to demonstrate that self-processing methods are applicable to these problems, and that MIRRORS/II, a general purpose software environment for implementing self-processing models, is sufficiently robust to support development of a wide range of application prototypes. Using MIRRORS/II and marker passing modelling techniques, a model of the execution of a Spaceworld plan was implemented. This is a simplified model of the Voyager spacecraft which photographed Jupiter, Saturn, and their satellites. It is shown that plan execution, a task usually solved using traditional artificial intelligence (AI) techniques, can be accomplished using a self-processing network. The fact that self-processing networks were applied to other space-related tasks, in addition to the one discussed here, demonstrates the general applicability of this approach to planning and control problems relevant to spacecraft activities. It is also demonstrated that MIRRORS/II is a powerful environment for the development and evaluation of self-processing systems. Author

N89-26588# McDonnell-Douglas Space Systems Co., Cocoa Beach, FL

**AN APPROACH TO KNOWLEDGE ENGINEERING TO SUPPORT KNOWLEDGE-BASED SIMULATION OF PAYLOAD GROUND PROCESSING AT THE KENNEDY SPACE CENTER**  
SHAWN MCMAHON and MICHAEL MCDANIEL In NASA, Goddard Space Flight Center, The 1989 Goddard Conference on Space Applications of Artificial Intelligence p 113-125 Apr. 1989  
Avail: NTIS HC A17/MF A03 CSCL 05/1

Planning for processing payloads was always difficult and time-consuming. With the advent of Space Station Freedom and its capability to support a myriad of complex payloads, the planning to support this ground processing maze involves thousands of man-hours of often tedious data manipulation. To provide the capability to analyze various processing schedules, an object oriented knowledge-based simulation environment called the Advanced Generic Accommodations Planning Environment (AGAPE) is being developed. Having nearly completed the baseline system, the emphasis in this paper is directed toward rule definition and its relation to model development and simulation. The focus is specifically on the methodologies implemented during knowledge acquisition, analysis, and representation within the AGAPE rule structure. A model is provided to illustrate the concepts presented. The approach demonstrates a framework for AGAPE rule development to assist expert system development. Author

N89-30128# RADEX, Inc., Bedford, MA  
**EVALUATION OF THE NSSDC (NATIONAL SPACE SCIENCE DATA CENTER) COMMON DATA FORMAT** Report, for Mar. 1988 - Mar. 1989

CAROLYN E. JORDAN and HOWARD J. SINGER 7 Mar. 1989  
20 p

(Contract F19628-87-C-0084)  
(AD-A207821; RX-890301; AFGL-TR-89-0078; SR-2) Avail: NTIS HC A03/MF A01 CSCL 05/2

The National Space Science Data Center has developed a data format system called the Common Data Format (CDF) which is designed to be useful to many different disciplines and flexible enough to accommodate many different types of data sets. The Air Force Geophysics Laboratory, Space Plasmas and Fields Branch has evaluated this format (VAX/VMS Fortran Version 1.0) comparing it to another common format system currently in use, the Flat Data Base Management System (FLATDBMS), and with Fortran direct access files with various record structures. The storage space required by the two packages is comparable to that

of the Fortran direct access files and not greatly in excess of that required by the data itself. Of the two packages, CDF is more flexible and is adaptable to a broader range of data sets. However, data retrieval is faster using the FLATDBMS. GRA

## 13

## ACCOMMODATIONS

Includes descriptions of simulations, analyses, trade studies, and requirements for safe efficient procedures, facilities, and support equipment on the ground and in space for processing, servicing, maintenance, reliability, commonality, verification and checkout of cargo and equipment.

**A89-38374**  
**EXPERIMENTAL INVESTIGATION FOR PROCESSING OF SEMICONDUCTORS AND BIO-MATERIALS IN SPACE USING SFU (SPACE FLYER UNIT)**

TOSHIYUKI TANAKA, MASAYA YAMAMOTO, TAKASHI NAKAJIMA (Hitachi, Ltd., Space Systems Div., Totsuka, Japan), NOBORU WAKASUGI, CHIAKI SHIMBO (Institute for Unmanned Space Experiments Free Flyer, Tokyo, Japan) et al. In: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 2515-2519. Research supported by the Ministry of International Trade and Industry and New Energy Development Organization. Copyright

The use of a gradient heating furnace, a mirror heating furnace, and an isothermal heating furnace on the first flight of the SFU is discussed. The purpose of these furnaces is to experimentally study materials processing in the space environment. Also to be flown on the SFU are biomaterial separation and purification equipment and biomaterial crystallization equipment. K.K.

**A89-38375**  
**DEVELOPMENT OF ISOTHERMAL HEATING FURNACE ONBOARD SFU (SPACE FLYER UNIT)**

TAKASHI KANAKUBO, MASARU YAMAMOTO, MASATSUGU AKIYAMA (Hitachi, Ltd., Yokohama, Japan), NOBORU WAKASUGI, CHIAKI SHIMBO (Institute for Unmanned Space Experiments Free Flyer, Tokyo, Japan) et al. In: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 2521-2525. Research supported by the Ministry of International Trade and Industry. Copyright

Studies of the isothermal heating furnace (IHF) function, specification, and construction were performed and the basic configuration of the IHF was defined. The IHF is characterized by a multifurnace configuration so that a number of experiments can be carried out without sample exchange. In effect, the IHF does not have moving parts generating microgravity disturbance. K.K.

**A89-45747**  
**A COMMONALITY ASSESSMENT OF LUNAR SURFACE HABITATION**

LISA GUERRA (Large Scale Programs Institute, Austin, TX) In: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 274-286. Research supported by the Large Scale Programs Institute. refs Copyright

NASA has baselined the Space Station common module for initial lunar base habitation. The present paper extends the NASA baseline beyond the definition phase by providing a parametric habitation study involving the current common module design. The adaptability of the Space Station module to the lunar environment is discussed, and analyses of the key supporting systems

# 13 ACCOMMODATIONS

(environmental control and life support, active thermal control, and radiation protection) are presented. A matrix modeling methodology is used to define the design requirements and attributes of the systems, with emphasis on the volume, mass, power requirements, and waste heat generated. B.J.

AB9-45772

**SPACECRAFT ENVIRONMENTS - DESIGN CONSIDERATIONS**  
R. O. RANTANEN (Science and Engineering Associates, Inc., Englewood, CO) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 575-583. refs  
Copyright

The following components of the overall spacecraft environment are discussed in connection with the problem of contamination control and environmental effects: neutral molecular environment, natural background, ambient atmosphere/spacecraft interactions, plasma perturbations, orbital debris and micrometeoroids, and other particulates. The expected levels of contamination and adverse environmental interactions for a given mission strongly depend on operational altitude, spacecraft size and configuration, and mission objectives. Environmental modeling is noted to be an indispensable component of spacecraft design practice. B.J.

AB9-45785\* National Aeronautics and Space Administration, Ames Research Center, Moffett Field, CA.

## SPACE ARTIFICIAL GRAVITY FACILITIES - AN APPROACH TO THEIR CONSTRUCTION

P. F. WERCINSKI (NASA, Ames Research Center, Moffett Field, CA), N. D. SEARBY (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA), and B. W. TILLMAN (Tillman Consulting, Carmel Valley, CA) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 734-749. refs  
Copyright

In the course of adaptation to a space microgravity environment, humans experience cardiovascular deconditioning, loss of muscle mass, and loss of bone minerals. One possible solution to these space adaptation problems is to simulate earth's gravity using the centripetal acceleration created by a rotating system. The design and construction of rotating space structures pose many challenges. Before committing to the use of artificial gravity in future space missions, a man-rated Variable Gravity Research Facility (VGRF) should be developed in earth orbit as a gravitational research tool and testbed. This paper addresses the requirements and presents preliminary concepts for such a facility. Author

AB9-45786

## ADAPTABLE CREW FACILITIES FOR FUTURE SPACE MODULES

DAVID NIXON (Future Systems Consultants, Los Angeles, CA), CHRISTOPHER MILLER, and REGIS FAUQUET IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 750-761. refs  
Copyright

Studies at NASA-Ames Research Center on advanced crew accommodation features for the Space Station are discussed. Life-size interior module crew environments and facilities and prototype accommodation features have been constructed for the habitability and laboratory modules. The general accommodation concept is outlined and the utility systems and distribution, structural spine, attachments, and rack and compartment geometry are described. Emphasis is placed on research to improve the habitability of the modules. R.B.

AB9-45791\* Grand Valley State Coll., Allendale, MI.

**LOGISTICS SUPPORT OF SPACE FACILITIES**  
WILLIAM C. LEWIS (Grand Valley State University, Allendale, MI) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988.

New York, American Society of Civil Engineers, 1988, p. 797-808. Research supported by NASA and American Society of Engineering Educators.

Copyright

The logistic support of space facilities is described, with special attention given to the problem of sizing the inventory of ready spares kept at the space facility. Where possible, data from the Space Shuttle Orbiter is extrapolated to provide numerical estimates for space facilities. Attention is also given to repair effort estimation and long duration missions. Author

AB9-45799

## COMPARISONS BETWEEN SPACE FACILITIES AND EARTH-BASED ANALOGS

JASON KLASSI (Design Science International, Los Angeles, CA) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 882-891. refs  
Copyright

Design features common to all habitat facilities built for/in harsh and isolated environments are examined. Special attention is given to designs of the Mobile Field Laboratory (MFL) system built for Antarctica, the Undersea Observatory to be built in Catalina (California), and to the comparison of these designs with the interiors of the Spacehab module and the Space Station and the Space Shuttle external tank/air cargo compartment. It is emphasized that, when designing facilities to be constructed in harsh and isolated environments on earth, or as orbiting or planetary habitats, some common design considerations apply to all. These include a careful site selection; the avoidance of large transportation and construction equipment; limitations on crew population size; and the emphasis upon reprocessing, reuse, and control of waste materials. I.S.

AB9-47130\*# NASA Space Station Program Office, Reston, VA.

## SPACE STATION FREEDOM - ACCOMMODATION FOR TECHNOLOGY R&D

ALAN C. HOLT (NASA, Space Station Freedom Program Office, Reston, VA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 20 p. refs (AIAA PAPER 89-2858) Copyright

The paper examines the features of the accommodation equipment designed for the candidate technology payloads of the Space Station, which include magnetic plasma thruster systems and a hypothetical advanced electromagnetic propulsion system utilizing high-temperature superconductivity materials. The review of the accommodation-equipment concepts supports the assumption that some propulsion technologies can be tested on the Space Station while being attached externally to the station's truss structure. For testing technologies with inherent operation or performance hazards, space platforms and smaller free-flyers coordinated with the Space Station can be used. Diagrams illustrating typical accommodation equipment configurations are included. I.S.

AB9-47180#

## THE SPACE VAN

LEN CORMIER (Third Millennium, Inc., Reno, NV) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. (AIAA PAPER 89-2946) Copyright

The Space Van, a small, reusable, two-stage rocket-powered space transportation system, has been developed. The configuration, performance, operational characteristics, launch-service prices, and potential applications of the Space Van system are discussed. The booster, cargo stage, orbiter stage, delayed recovery stage, and external LOX tanks for service to LEO are described. For service beyond LEO, a small expendable transfer stage, an expendable orbital transfer vehicle, and an RL10 rocket engine are used. Applications of the Space Van include the Space Station, defense, launching space probes, commercial

space transportation, manufacturing, telecommunications, solar power, on-orbit servicing and repair, and debris clearance. R.B.

#### AB9-47326

#### AEROSPACE BEHAVIORAL TECHNOLOGY CONFERENCE AND EXPOSITION, 7TH, ANAHEIM, CA, OCT. 3-4, 1988, PROCEEDINGS

Conference and Exposition sponsored by SAE, Warrendale, PA, Society of Automotive Engineers, Inc. (SAE P-216), 1989, 183 p. For individual items see AB9-47327 to AB9-47342. (SAE P-216) Copyright

Topics discussed in these proceedings include those on the cockpit, space, workload, crew awareness, air transport system automation, fitness for duty, concerns of the international pilots, training technologies, and graphic tools for cockpit design. Papers are presented on display requirements for a threat response system; flight crew displays for Space Station proximity operations; EVA design integration for Space Station assembly; an assessment of crew workload procedures in full fidelity; the definition, measurement, and enhancement of the situational awareness in the commercial flight deck; and current and future trends in automation in transport aircraft. Attention is also given to the design of crew rest quarters, airline operations and the contaminated runway, the role of flight planning in aircrew decision performance, requirements for rapid prototyping of crew station displays, and human factors engineering workstation for model-based cockpit design. I.S.

#### AB9-48168#

#### RELIABILITY AND MAINTAINABILITY ALLOCATION FOR WORK PACKAGE ONE OF THE SPACE STATION FREEDOM PROGRAM

KENNETH G. NEUSCHAEFER and DAVID D. NEAL (Boeing Aerospace and Electronics, Huntsville, AL) AIAA and NASA, Symposium on the Maintainability of Aerospace Systems, Anaheim, CA, July 26, 27, 1989, 7 p. (AIAA PAPER 89-5057) Copyright

On the Space Station Freedom Program, traditional quantitative reliability and maintainability (R&M) requirements were replaced by a matrix of maintenance manhour per year (MMH/Y) requirements. This paper describes the R&M allocation model that was developed for Work Package 1. The allocation model generates traditional R&M allocations at a low enough level to influence the design process and assure that overall MMH/Y requirements are achieved. The allocation model is composed of four sections: MMH/Y requirements; current predictions or estimates (based on MTBF, MTTR and scheduled maintenance); MMH/Y allocations; and MTBF, MTTR and scheduled maintenance allocations. The model is designed to run on a personal computer using standard spreadsheet software. Author

#### AB9-48567\*# General Research Corp., McLean, VA.

#### SPACE-BASED TEST-BED CONCEPT

CHARLES F. GARTRELL and CYRUS L. BUTNER (General Research Corp., McLean, VA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 26, July-Aug. 1989, p. 245-251. refs (Contract NASW-4138) Copyright

The space test-bed (STB) conceptual design proposed as a basis for the long-term experimental development of advanced spacecraft bus technology with minimum technological risk consists of a main spacecraft bus, whose subsystems furnish the common support functions for the entire facility, and detachable/detachable experimental pallets. The STB design requires only modest enhancements of current systems and techniques, with many off-the-shelf components. The economics of the STB are presently emphasized. O.C.

#### AB9-48716

#### MANNED SYSTEMS AND SUPPORTING TECHNOLOGIES - CREW WORKSTATION, TELESCIENCE AND EGSE

F. DI TOLLE and F. LONGONI (LABEN Industrie per lo Spazio e le Comunicazioni S.p.A., Milan, Italy) (ESA, Ministry for Science

and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 87-96. refs Copyright

The main technological aspects in the support of manned space systems and their utilization scenario are outlined. The implementation of the telepresence concepts, the definition of the crew workstation, and the development of the related ground support equipment in the frame of the future manned space stations are addressed. Emphasis is given to aspects relevant to the Columbus Space Station scenario, including the European Ground Support Equipment (EGSE). C.D.

#### AB9-51848\* NASA Space Station Program Office, Reston, VA.

#### SPACE STATION PAYLOAD ACCOMMODATIONS

LOUIS HEMMERDINGER (Grumman Corp., Space Station Program Support Div., Reston, VA) and ALAN HOLT (NASA, Space Station Utilization and Operations Group, Reston, VA) IN: Space Commerce; Proceedings of the Second International Conference and Exhibition on the Commercial and Industrial Uses of Outer Space, Montreux, Switzerland, Feb. 21-25, 1988, New York, Gordon and Breach Science Publishers, 1988, p. 261-281. Copyright

Accommodating a multitude of diverse payloads on the Space Station base and its platforms requires an early definition of payload candidates to assure an adequate assessment of payload requirements. The task of interpreting the payload requirements, translating them into Station design requirements, and developing the processes and procedures to accommodate and integrate the user onto the Station is the function of the NASA Space Station Program Office Utilization and Operations Group. This paper describes the Space Station assembly sequence, time-phased payload accommodations, and the unique research environment provided by the Space Station. Author

#### AB9-52605\*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.

#### A POINTING SYSTEM DESIGN CONCEPT FOR SPACE STATION ATTACHED PAYLOADS

EDWARD WONG, DAVE RATHBUN, and KENNETH SMITH (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 759-769. refs (AIAA PAPER 89-3513) Copyright

A study has been conducted to recommend a pointing system design and architecture that can accommodate the articulated pointing requirements levied on the Space Station Freedom Attached Payload Pointing System. A conceptual design of a control system is developed using classical rate and position control techniques. A high fidelity simulation testbed has been developed as the principal tool for the pointing performance evaluation. Techniques of model reduction are applied to reduce the model order to a manageable size for incorporation into the testbed. The disturbance rich space station environment has been modeled, and nonlinearities such as bearing friction, motor and sensor noise are also considered. Simulations were performed with representative payloads at nominal pointing orientations. The results show that the tight instrument pointing requirements and the severe Space Station disturbance environment render a marginal performance for a conventional (direct drive and hardmount) gimbal pointing system, particularly for lightweight payloads. A gimbal system that incorporates a passive base isolator and reactionless actuation appears to provide a significant improvement in pointing performance over the conventional pointing systems. Author

#### AB9-52607#

#### INSTABILITY OF AN EARTH POINTING SPACE STATION DUE TO INTERNAL MASS MOTION

C. H. SPENNY and T. E. WILLIAMS (USAF, Institute of Technology, Wright-Patterson AFB, OH) IN: AIAA Guidance, Navigation and



## 13 ACCOMMODATIONS

Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 781-791. refs  
(AIAA PAPER 89-3515)

The attitude stability of an earth-pointing space station subjected to periodic translation of the crew or equipment is considered. It is shown that instability may occur if the period of motion is in the range of one-half to two times the orbital period. Such periodic motion may result, for example, from experimentation that would require crew or mass shifting to the 'earth end' of the station at each passover of a ground location. Instability occurs for a range of station configurations expressed as two principal moment of inertia ratios. The larger the moving internal mass and the larger its amplitude of motion, the wider the region of instability. Results are presented for mass motion along the station axis that nominally is aligned to the local vertical. However, the equations of motion for gravity-gradient stabilization are presented for a space station modelled as a rigid body with a point moving mass that can translate along any principal axis. Author

### **ABN-53296\*#** NASA Space Station Program Office, Reston, VA. **WHAT'S ON FREEDOM FOR USERS?**

RICHARD J. WILLIAMS, ROBERT A. DORIAN, and ALAN C. HOLT (NASA, Space Station Freedom Program Office, Reston, VA) Aerospace America (ISSN 0740-722X), vol. 27, Sept. 1989, p. 20-22, 24. Copyright

The design and use of the Space Station Freedom are discussed. The contributions to the Station from EAS, Japan, Canada, and the US are described. Consideration is given to the capability of the Station, the internal accommodations for crew and payloads, various applications for the modules, and the planning and operation of the payloads. I.F.

### **ABN-54694#**

#### **ZERO-G GROUND TEST SIMULATION METHODS**

ROY IKEGAMI, M. ZACK ECKBLAD, JOHN E. BLACKMAN, and ROY K. WATANABE (Boeing Aerospace, Seattle, WA) IN: Aerospace Testing Seminar, 11th, Manhattan Beach, CA, Oct. 11-13, 1988, Proceedings, Mount Prospect, IL, Institute of Environmental Sciences, 1988, p. 215-226.

Zero-g simulation techniques for use in ground tests of large space structures are assessed. A distributed support system which uses long suspension cables and soft springs to support the structure was found to be the most promising suspension concept to simulate a zero-g environment on earth. Each significant portion of the test article is suspended from a high ceiling by light weight cables and soft springs. The system is characterized by simplicity, low cost, predictability, and an ability to provide long test durations. K.K.

### **ABN-54695\*#** National Aeronautics and Space Administration, John F. Kennedy Space Center, Cocoa Beach, FL.

#### **SPACE STATION LAUNCH SITE PROCESSING**

JOHN G. OERTEL (NASA, Kennedy Space Center, Cocoa Beach, FL) and JOHN W. ELBON, III (NASA, Kennedy Space Center; McDonnell Douglas Astronautics Co., Cocoa Beach, FL) IN: Aerospace Testing Seminar, 11th, Manhattan Beach, CA, Oct. 11-13, 1988, Proceedings, Mount Prospect, IL, Institute of Environmental Sciences, 1988, p. 227-235.

Planning which is underway at NASA-Kennedy toward launch site processing of Space Station elements is described. The goal is to develop cost-effective processing for each of the Program elements. Launch site receiving is discussed as well as post delivery verification, prelaunch assembly, prelaunch testing, experiment integration, and testing and servicing. K.K.

### **ABN-20324\*#** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

#### **LOW FREQUENCY VIBRATION ISOLATION TECHNOLOGY FOR MICROGRAVITY SPACE EXPERIMENTS**

CARLOS M. GROSSINSKY and GERALD V. BROWN 1989 10 p Proposed for presentation at the 12th Biennial Conference

on Mechanical Vibration and Noise, Montreal, Quebec, 17-20 Sep. 1989; sponsored by ASME

(NASA-TM-101448; E-4557; NAS 1.15:101448) Avail: NTIS HC A02/MF A01 CSCL 13/2

The dynamic acceleration environment observed on Space Shuttle flights to date and predicted for the Space Station has complicated the analysis of prior microgravity experiments and prompted concern for the viability of proposed space experiments requiring long-term, low-g environments. Isolation systems capable of providing significant improvements in this environment exist, but have not been demonstrated in flight configurations. This paper presents a summary of the theoretical evaluation for two one degree-of-freedom (DOF) active magnetic isolators and their predicted response to both direct and base excitations, that can be used to isolate acceleration sensitive microgravity space experiments. Author

### **ABN-22336\*#** National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, AL.

#### **VIDEO REQUIREMENTS FOR MATERIALS PROCESSING EXPERIMENTS IN THE SPACE STATION US LABORATORY**

CHARLES R. BAUGHER IN: NASA, Goddard Space Flight Center, Proceedings of the Scientific Data Compression Workshop p 119-126 Feb. 1989

Avail: NTIS HC A19/MF A03 CSCL 22/1

Full utilization of the potential of the materials research on the Space Station can be achieved only if adequate means are available for interactive experimentation between the science facilities and ground-based investigators. Extensive video interfaces linking these three elements are the only alternative for establishing a viable relation. Because of the limit in the downlink capability, a comprehensive complement of on-board video processing, and video compression is needed. The application of video compression will be an absolute necessity since its effectiveness will directly impact the quantity of data which will be available to ground investigator teams, and their ability to review the effects of process changes and the experiment progress. Video data compression utilization on the Space Station is discussed. Author

### **ABN-24421\*#** National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, AL.

#### **A METHODOLOGY FOR COMMONALITY ANALYSIS, WITH APPLICATIONS TO SELECTED SPACE STATION SYSTEMS**

LAWRENCE DALE THOMAS May 1989 99 p (NASA-TM-100364; NAS 1.15:100364) Avail: NTIS HC A05/MF A01 CSCL 22/2

The application of commonality in a system represents an attempt to reduce costs by reducing the number of unique components. A formal method for conducting commonality analysis has not been established. In this dissertation, commonality analysis is characterized as a partitioning problem. The cost impacts of commonality are quantified in an objective function, and the solution is that partition which minimizes this objective function. Clustering techniques are used to approximate a solution, and sufficient conditions are developed which can be used to verify the optimality of the solution. This method for commonality analysis is general in scope. It may be applied to the various types of commonality analysis required in the conceptual, preliminary, and detail design phases of the system development cycle. Author

### **ABN-28267#** British Aerospace Public Ltd. Co., Bristol (England). Space and Communications Div.

#### **LONG-LIFE STIRLING CYCLE COOLERS FOR APPLICATIONS IN THE 60 TO 110 K RANGE**

C. A. LEWIS IN: ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 387-391 Dec. 1988

Copyright Avail: NTIS HC A09/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

A mechanical, long life refrigerator which can replace stored cryogenics and low temperature radiators in the 60 to 110 K range is presented. Design guidelines are given for the accommodation

of these coolers on 3-axis and spin stabilized spacecraft. The growth of a cooler system from a single unit may require additional hardware such as thermal switches, momentum compensators, and cold plumbing. A modular philosophy towards this cryogenic hardware is proposed, enabling the user to design a system which exactly meets the mission requirements with respect to performance, reliability and flexibility. ESA

**N89-28268#** Rutherford High Energy Lab., Chilton (England).

**A 4-K MECHANICAL REFRIGERATOR FOR SPACE APPLICATIONS**

T. V. BRADSHAW and A. H. ORLOWSKA. In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 393-397 Dec. 1988

Copyright Avail: NTIS HC A89/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

A long life 4 K mechanical refrigerator for space applications was developed. The refrigerator consists of a Stirling cycle precooler operating at 20 K and a Joule-Thomson system using helium to achieve temperatures in the region of 4 K with a cooling power of a few milliwatts. The precooler is a two stage Stirling cycle cooler and is based on earlier work on long life single stage coolers. The Joule-Thomson stage uses compressors that are similar to those used in the precooler. ESA

**N89-29468#** Martin Marietta Corp., New Orleans, LA.

**ON-ORBIT METROLOGY AND CALIBRATION REQUIREMENTS FOR SPACE STATION ACTIVITIES DEFINITION STUDY Final Report**

G. M. COTTY, B. N. RANGANATHAN, and A. L. SORRELL 1989 202 p

(Contract NAS14-303)

(NASA-CR-185821; NAS 1.26:185821) Avail: NTIS HC A10/MF A02 CSCL 22/2

The Space Station is the focal point for the commercial development of space. The long term routine operation of the Space Station and the conduct of future commercial activities suggests the need for in-space metrology capabilities analogous when possible to those on-Earth. The ability to perform periodic calibrations and measurements with proper traceability is imperative for the routine operation of the Space Station. An initial review, however, indicated a paucity of data related to metrology and calibration requirements for in-space operations. This condition probably exists because of the highly developmental aspect of space activities to date, their short duration, and nonroutine nature. The on-orbit metrology and calibration needs of the Space Station were examined and assessed. In order to achieve this goal, the following tasks were performed: an up-to-date literature review; identification of on-orbit calibration techniques; identification of sensor calibration requirements; identification of calibration equipment requirements; definition of traceability requirements; preparation of technology development plans; and preparation of the final report. Significant information and major highlights pertaining to each task is presented. In addition, some general (generic) conclusions/observations and recommendations that are pertinent to the overall in-space metrology and calibration activities are presented. Author

STEVE JOHNSON. In: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 852-863. refs

Copyright

A second generation space station in a halo orbit at Libration Point 1 (L1) is proposed. It is suggested that a station at L1 would be easily accessed from LEO, well situated for servicing GEO, and would provide low delta-V access to the moon and Mars. The possible missions which would be associated with a station at L1 are outlined. The proposed station includes a closed ecological life support system and artificial gravity to aid in ensuring that the station is self-supporting and to maximize astronaut health. R.B.

**A89-53458\*** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

**THE SPACE STATION FREEDOM EVOLUTION-PHASE - CREW-EVA DEMAND FOR ROBOTIC SUBSTITUTION BY TASK PRIMITIVE**

JEFFREY H. SMITH, JAY ESTUS, CATE HENEGHAN, and CHARLES NAINAN (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) In: 1989 IEEE International Conference on Robotics and Automation, Scottsdale, AZ, May 14-19, 1989, Proceedings, Volume 3, Washington, DC, IEEE Computer Society Press, 1989, p. 1472-1477. refs

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Space Station Freedom represents a significant demand for automation and robotics services as substitutes for crew EVAs. Results are reported from a study aimed at identifying the demand for crew EVA and the crew-task primitive distributions derived for input to future robotic substitution studies. Generic EVA tasks are developed from historical EVA mission timelines, and a set of 70 task primitives defined. The generic task activities are partitioned into task setup, kernel, and tear-down, with standardized task times and frequencies. These standardized times are coupled with inputs from numerous mission data bases in a probabilistic simulation to obtain estimates of total crew-EVA task time demand by crew task primitive. The use of probabilistic model is found to be crucial for understanding, isolating, and addressing the large uncertainties in the EVA task kernels. I.E.

**N89-21026#** National Aeronautics and Space Administration, Washington, DC.

**NASA DIRECTIONS IN SPACE PROPULSION FOR 2000 AND BEYOND**

GREGORY M. RECK 1989 12 p Presented at the Symposium on Space Commercialization: Roles of Developing Countries, Nashville, TN, 5-10 Mar. 1989

(NASA-TM-102281; NAS 1.15:102281) Avail: NTIS HC A03/MF A01 CSCL 21/8

In his National Space Policy of 1988, President Reagan committed to a goal of expanding human presence and activity in the solar system. This goal has provided the impetus for a resurgence of activity in a broad range of space technology efforts in general and for a number of propulsion technology programs in particular. Building on recommendations from several detailed studies of the U.S. space program, NASA has increased the level of investment in propulsion technology development. The Civil Space Technology Initiative is developing propulsion technology in support of near-Earth operations. These efforts are focused on both main and booster engines and seek to provide design methods and databases to support future developments of low cost, reliable transportation systems. Program elements include turbomachinery, combustion systems, and condition monitoring and diagnostics, and the design methodology developed at component levels will be verified in large scale systems. The Pathfinder program is developing a suite of technologies to enable a broad range of manned and unmanned missions beyond Earth's orbit. These include both chemical and electric propulsion technologies to support potential missions to the moon and Mars. Author

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### GROWTH

Includes descriptions of scenarios, analyses and system technology requirements for the evolutionary growth of the Space Station system.

**A89-45796**

**THE SECOND GENERATION SPACE STATION**

MARVIN W. LUTTGES (Colorado, University, Boulder) and A.

**N89-23517\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

#### PHOTOVOLTAIC POWER SYSTEM CONSIDERATIONS FOR FUTURE LUNAR BASES

DENNIS J. FLOOD and JOSEPH APPELBAUM 1989 8 p Presented at International PVSEC-4, Sydney, Australia, 14-17 Feb. 1989; sponsored by The Institution of Radio and Electronics Engineers of Australia and The University of New South Wales (NASA-TM-102019; E-4744; NAS 1.15:102019) Avail: NTIS HC A02/MF A01 CSCL 10/2

The cost of transportation to the lunar surface places a premium on developing ultralightweight power system technology to support the eventual establishment of a lunar base. The photovoltaic technology issues to be addressed by the Surface Power program element of NASA's Project Pathfinder are described. Author

**N89-25272\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

#### SPACE NUCLEAR REACTOR SHIELDS FOR MANNED AND UNMANNED APPLICATIONS

BARBARA I. MCKISSOCK and HARVEY S. BLOOMFIELD 1989 16 p Presented at the International Conference on Space Power, Cleveland, OH, 5-7 Jun. 1989; sponsored by the International Astronautical Federation (NASA-TM-102064; E-4821; NAS 1.15:102064) Avail: NTIS HC A03/MF A01 CSCL 10/2

Missions which use nuclear reactor power systems require radiation shielding of payload and/or crew areas to predetermined dose rates. Since shielding can become a significant fraction of the total mass of the system, it is of interest to show the effect of various parameters on shield thickness and mass for manned and unmanned applications. Algorithms were developed to give the thicknesses needed if reactor thermal power, separation distances, and dose rates are given as input. The thickness algorithms were combined with models for four different shield geometries to allow tradeoff studies of shield volume and mass for a variety of manned and unmanned missions. Shield design tradeoffs presented in this study include the effects of: higher allowable dose rates; radiation hardened electronics; shorter crew exposure times; shield geometry; distance of the payload and/or crew from the reactor; and changes in the size of the shielded area. Specific NASA missions that were considered in this study include unmanned outer planetary exploration, manned advanced/evolutionary space station, and advanced manned lunar base. Author

**N89-26905\*** Rockwell International Corp., Canoga Park, CA. Rocketdyne Div.

#### SPACE STATION HYDROGEN/OXYGEN THRUSTER TECHNOLOGY Final Report

G. L. BRILEY and R. S. IACABUCCI Nov. 1988 111 p (Contract NAS3-25142) (NASA-CR-182280; NAS 1.26:182280; RI/RD88-256) Avail: Issuing Activity CSCL 21/8

The effort expended by the Rocketdyne Division of Rockwell International in fulfilling the requirements of the Space Station Freedom Hydrogen/Oxygen Thruster Technology program is discussed. Included are the basis and the rationale for the design of the thruster, injector, and nozzle; the test results; and the lessons learned, together with conclusions and recommendations for the development of the Space Station Freedom thrusters. Author

**N89-26576\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

#### EVOLUTIONARY GROWTH FOR SPACE STATION FREEDOM ELECTRICAL POWER SYSTEM

MATTHEW F. MARSHALL, KERRY L. MCLALLIN, and MICHAEL J. ZERNIC 1989 8 p Presented at the 24th Intersociety Energy Conversion Engineering Conference, Washington, DC, 6-11 Aug. 1989; cosponsored by IEEE, AIAA, ANS, ASME, SAE, ACS, and AIChE (NASA-TM-102339; E-5047; NAS 1.15:102339) Avail: NTIS HC A02/MF A01 CSCL 22/2

Over an operational lifetime of at least 30 yr, Space Station Freedom will encounter increased space station user requirements and advancing technologies. The space station electrical power system is designed with the flexibility to accommodate these emerging technologies and expert systems and is being designed with the necessary software hooks and hardware scars to accommodate increased growth demand. The electrical power system is planned to grow from the initial 75 kW up to 300 kW. The Phase 1 station will utilize photovoltaic arrays to produce the electrical power; however, for growth to 300 kW, solar dynamic power modules will be utilized. Pairs of 25 kW solar dynamic power modules will be added to the station to reach the power growth level. The addition of solar dynamic power in the growth phase places constraints in the initial space station systems such as guidance navigation and control, external thermal, truss structural stiffness, computational capabilities and storage which must be planned-in in order to facilitate the addition of the solar dynamic modules. Author

## MISSIONS, TETHERS, AND PLATFORMS

Includes descriptions and requirements of missions and tethers onboard the Space Station and platforms that are either co-orbiting with the Space Station, in polar orbit, or in geosynchronous orbit and which are part of the Space Station system.

#### A89-34267\* General Electric Co., Princeton, NJ. CARBON DIOXIDE DOPPLER LIDAR WIND SENSOR ON A SPACE STATION POLAR PLATFORM

JOHN C. PETHERAM, GRETA FROHBEITER, and A. ROSENBERG (General Electric Co., Astro-Space Div., Princeton, NJ) Applied Optics (ISSN 0003-6905), vol. 28, March 1, 1989, p. 834-839. refs (Contract JPL-957746) Copyright

A study has been performed of the feasibility of accommodating a carbon dioxide Doppler lidar on a Space Station polar platform. Results show that such an instrument could be accommodated on a single 1.5 x 2.25-m optical bench, mounted centrally on the earth facing side of the satellite. The power, weight, and thermal issues appear resolvable. However, the question of servicing the instrument remains open, until more data are available on the lifetime of an isotopic CO<sub>2</sub> laser. Author

#### A89-35795\* Stanford Univ., CA. CLOSED LOOP NAVIGATION AND GUIDANCE FOR GRAVITY PROBE B ORBIT INSERTION

P. AXELRAD and B. W. PARKINSON (Stanford University, CA) Navigation (ISSN 0026-1522), vol. 36, Spring 1989, p. 45-61. refs (Contract NAS8-26125) Copyright

This paper addresses the problem of guiding the Gravity Probe B (GP-B) spacecraft from its location after initial insertion to a very precise low earth orbit. Specifically, the satellite orbit is required to be circular to within 0.001 eccentricity, polar to within 0.001 deg inclination, and aligned with the direction of the star Rigel to within 0.001 deg. Navigation data supplied by an on-board GPS receiver is used as feedback to a control algorithm designed to minimize the time to achieve the desired orbit. Translational control is provided by the proportional helium thrusters, which are used for drag-free and attitude control during the remainder of the science mission. Simulations of the guidance system are presented which give an indication of performance characteristics for several types of orbit injection errors. This research is the first reported effort to use GPS as a sensor for a closed loop space guidance system. Author



**A89-36941\*** Harvard-Smithsonian Center for Astrophysics, Cambridge, MA.

**DYNAMICS AND CONTROL OF THE TETHER ELEVATOR/CRAWLER SYSTEM**

E. C. LORENZINI, M. COSMO (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA), S. VETRELLA, and A. MOCCIA (Napoli, Università, Naples, Italy) (PSN, NASA, ESA, AIDAA, AIAA, and AAS, International Conference on Tethers in Space, 2nd, Venice, Italy, Oct. 4-8, 1987) *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090), vol. 12, May-June 1989, p. 404-411. Research supported by CNR. refs  
(Contract NAS8-36606)

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This paper investigates the dynamics and acceleration levels of a new tethered system for micro- and variable-gravity applications. The system consists of two platforms tethered on opposite sides to the Space Station. A fourth platform, the elevator, is placed in between the Space Station and the upper platform. Variable-g levels on board the elevator are obtained by moving this facility along the upper tether, while microgravity experiments are carried out on board the Space Station. By controlling the length of the lower tether the position of the system center of mass can be maintained on board the Space Station despite variations of the system's distribution of mass. The paper illustrates the mathematical model, the environmental perturbations and the control techniques which have been adopted for the simulation and control of the system dynamics. Two sets of results from two different simulation runs are shown. The first set shows the system dynamics and the acceleration spectra on board the Space Station and the elevator during station-keeping. The second set of results demonstrates the capability of the elevator to attain a preselected g-level.

Author

**A89-36945\***

**EFFECTS OF ATMOSPHERIC DENSITY GRADIENT ON CONTROL OF TETHERED SUBSATELLITES**

JUNJIRO ONODA and NAOKYU WATANABE (Tokyo, University, Japan) *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090), vol. 12, May-June 1989, p. 431-433. refs  
Copyright

A simple model is used to consider the effects of the atmospheric density gradient on the swinging motion of tension-controlled tethered subsatellites in LEO, as well as to design a suitable control system for the satellite. It is established that effects on the stability of a controlled system are more severe than on an uncontrolled one; a control system designed without taking the atmospheric density gradient into account can greatly destabilize the closed-loop system.

O.C.

**A89-37292\*** Virginia Polytechnic Inst. and State Univ., Blacksburg.

**COMPARISON OF THE MEASURED AND PREDICTED RESPONSE OF THE EARTH RADIATION BUDGET EXPERIMENT ACTIVE CAVITY RADIOMETER DURING SOLAR OBSERVATIONS**

J. R. MAHAN, N. E. TIRA (Virginia Polytechnic Institute and State University, Blacksburg), ROBERT B. LEE, III, and R. J. KEYNTON (NASA, Langley Research Center, Hampton, VA) *Applied Optics* (ISSN 0003-6935), vol. 28, April 1, 1989, p. 1327-1337. refs  
(Contract NAS1-18106)

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The Earth Radiation Budget Experiment consists of an array of radiometric instruments placed in earth orbit by the National Aeronautics and Space Administration to monitor the longwave and visible components of the earth's radiation budget. Presented is a dynamic electrothermal model of the active cavity radiometer used to measure the earth's total radiative exitance. Radiative exchange is modeled using the Monte Carlo method and transient conduction is treated using the finite element method. Also included is the feedback circuit which controls electrical substitution heating of the cavity. The model is shown to accurately predict the dynamic response of the instrument during solar calibration.

Author

**A89-38247**

**ON THE TETHER TECHNOLOGY REALIZING A MICROGRAVITY LABORATORY DEPLOYED IN THE PROXIMITY OF THE LARGE MOTHER SPACESHIP**

SHOICHI YOSHIMURA and TAISUO YAMANAKA (National Aerospace Laboratory, Chofu, Japan) IN: *International Symposium on Space Technology and Science*, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1621-1626. refs  
Copyright

A study has been carried out on the tether technology realizing the microgravity environment (0.0001-0.00001 G) in a tethered small satellite deployed in the proximity of a large mother spaceship. Cutting off or at least attenuating the propagation of the g-jitters from the mother spaceship, the tether would provide the microgravity environment inside the tethered satellite. Numerical simulations of the tether system dynamics with and without control are now being carried out.

Author

**A89-38891\*** National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, AL.

**THE SPACELAB 2 MISSION - AN OVERVIEW**

EUGENE W. URBAN and K. STUART CLIFTON (NASA, Marshall Space Flight Center, Huntsville, AL) *Astrophysical Letters and Communications* (ISSN 0888-6512), vol. 27, no. 3, 1988, p. 133-139. refs  
Copyright

A summary is presented of the results of experiments on the Spacelab 2 mission, which was flown on the Shuttle Orbiter between July 29 and August 6, 1985. The background and flight of the mission and the payload configuration are examined. The experiments include the Ejectable Plasma Diagnostics Package, Vehicle Charging and Potential Experiment, and plasma detection experiments. Life science experiments include studies of the effects of spaceflight on the growth of plant tissues and perturbations of bone and calcium homeostasis in flight crew members. Solar studies include the Solar UV Spectral Irradiance Monitor, the Coronal Helium Abundance Spacelab Experiment, the High Resolution Telescope and Spectrograph, the Solar Magnetic and Velocity Field Measurement System, and the Solar Optical Universal Polarimeter. Additional experiments include observations with a small He-cooler IR telescope, Hard X-ray imaging of galaxy clusters and extended X-ray sources, the composition and energy spectra of cosmic ray nuclei, and the properties of superfluid He in zero gravity.

R.B.

**A89-39743\*** National Aeronautics and Space Administration, Washington, DC.

**BEYOND EARTH'S BOUNDARIES**

ALAN LADWIG (NASA, Office of Exploration, Washington, DC) and TERRI RAMLOSE (Science Applications International Corp., Schaumburg, IL) *Space Policy* (ISSN 0265-9646), vol. 5, May 1989, p. 138-146.

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Four candidate missions for exploring the solar system and establishing human settlements beyond earth orbit are described. Human expeditions to Phobos and Mars, the establishment of a lunar observatory, and the creation of lunar outpost for use in Mars exploration are examined. Near-term programs are discussed, including studies of earth-to-orbit transportation, life science research, robotic precursor missions, and the Space Station.

R.B.

**A89-40176**

**INTERNATIONAL CONFERENCE ON TETHERS IN SPACE - TOWARD FLIGHT, 3RD, SAN FRANCISCO, CA, MAY 17-19, 1989, COLLECTION OF PAPERS AND ABSTRACTS**

Conference sponsored by AIAA, NASA, Agenzia Spaziale Italiana, and ESA, Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, 447 p. For individual items see A89-40177 to A89-40229.

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Papers concerning the use of tethers in space are presented,

## 15 MISSIONS, TETHERS, AND PLATFORMS

covering tether activities at NASA and in Italy and the FRG, flight demonstrations of the Small Expendable-Tether Deployer System and the Get-Away Tether Experiment, the use of Delta II for tether experiments, and the operational and safety issues related to tethers. Other topics include electrodynamic and tether, proposals for downward deployed tethers, tether dynamics and control strategies, the use of tethers in transportation, gravity and rotating tether systems, and the status of tether technology. Additional subjects include the impact of tethers on atmospheric science, the Tether Initiated Space Recovery System, electromagnetic applications of tethers, passive tethered satellite retrieval, a tether deployment monitoring system, tether materials, the Tethered Satellite System, and tethered telescopes, platforms, stations, and elevators. R.B.

**A89-40177\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.  
**SUMMARY OF THE SECOND INTERNATIONAL CONFERENCE ON TETHERS IN SPACE VENICE, ITALY, OCTOBER 4-8, 1987**  
JOSEPH C. KOLECKI (NASA, Lewis Research Center, Cleveland, OH) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. XV-XX. refs (AIAA PAPER 89-1547) Copyright

**A89-40178\*** Jet Propulsion Lab., California Inst. of Tech., Pasadena.  
**OVERVIEW OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION TETHER ACTIVITIES**  
PAUL A. PENZO (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 3-8. refs (AIAA PAPER 89-1548)

NASA research concerning the use of tethers in space is reviewed, including joint research with the Italian Space Agency. Tether applications under consideration are described, such as a tethered fuel depot and a tethered gravity laboratory platform for the Space Station, providing artificial gravity to and from Mars, payload recovery and waste management, aerothermodynamic magnetospheric physics, and electrodynamic propulsion, braking, and power generation for the Space Shuttle. Also, tether flight demonstrations are examined, including the Small Expendable Deployer System, the Get-Away Tether Experiment, the Tether Elevator Crawler System, and the Kinetic Isolation Tether Experiment. R.B.

**A89-40179\***  
**TETHER INTERESTS AND ACTIVITIES WITHIN GERMANY**  
W. SEBOLDT, J. PULS (DFVLR, Cologne, Federal Republic of Germany), W. HALLMANN, W. LEY (Aachen, Fachhochschule, Federal Republic of Germany), A. HORNIK (Muenchen, Technische Universität, Munich, Federal Republic of Germany) et al. IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 9-16. refs (AIAA PAPER 89-1549) Copyright

Tether research and flight demonstrations in the FRG are reviewed. Consideration is given to the role of German scientists in the Tethered Satellite System-1 mission, participation in ESA studies of tether applications and tether applications for Hermes/Man Tended Free Flyer. Tether demonstrations and experiments are discussed, including the Topas Tether Experiment, tether systems demonstrations for the Spas and Eureka platforms and the Space Courier reentry capsule. R.B.

**A89-40185\***  
**ELECTROMAGNETIC RADIATION PERFORMANCE OF SPACE-BASED TETHERED ARRAY ANTENNAS**

MICHAEL S. KAPLAN and CYNTHIA A. KING (U.S. Navy, Naval Research Laboratory, Washington, DC) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 58-62. refs (AIAA PAPER 89-1555) Copyright

This paper describes an effort to determine the technical feasibility of a space-based tethered array antenna concept. The focus of this paper is on the electromagnetic radiation characteristics of this antenna. This concept consists of a collection of antenna elements tethered together and deployed near a spacecraft whose mass is much greater than the antenna to form a dynamic, quasi-linear phased array. This concept's feasibility depends on the ability of the antenna to produce radiation patterns useful for such applications as space-based radar. Initial results show that while the tether librations are small, they are still large enough to merit correction via signal processing. Author

**A89-40189\***  
**PASSIVE CURRENT COLLECTION**

W. B. THOMPSON (California, University, La Jolla) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 88-93. refs (AIAA PAPER 89-1559) Copyright

Consideration is given to the use of a conducting probe to collect substantial currents from the plasma environment for electromagnetic tether applications. The kinematics of current collection and the effects of small potentials are discussed. The quasi-neutral collection process is studied, showing that the plasma can be electrically neutral in two regimes: one in which the current drawn to the probe is very small, and one in which the saturation current is drawn. The effects of the wake on the plasma are examined, showing that the detailed current voltage characteristic depends more on collector geometry than on plasma effects. R.B.

**A89-40191\*** National Aeronautics and Space Administration, Washington, DC.  
**TETHERED SATELLITE SYSTEM-2 - A PROPOSED PROGRAM**  
JOHN L. ANDERSON (NASA, Washington, DC) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 103-108. refs (AIAA PAPER 89-1561) Copyright

A second mission (TSS-2) has been proposed for the reusable Tethered Satellite System (TSS) being developed jointly by the U.S. and Italy. The TSS-2 flight demonstration would use the TSS deployer/retriever system to deploy a research spacecraft attached to the end of a 100-km-long tether. The deployment would take place downward from the Space Shuttle into the outer atmosphere to an altitude of approximately 130 km. The objectives of the mission would be to demonstrate the atmospheric deployment of a tethered system, conduct scientific and aerothermodynamic research measurements, and conduct engineering measurements to verify flight system performance. Analytical studies have shown the feasibility of the TSS-2 mission from both the technology and operational dynamics standpoint. The TSS-1 mission (a 20 km tether deployed upward to conduct electrodynamic experiments) will validate the TSS itself as well as deployment and retrieval operations. Author

**A89-40193\*** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.  
**TETHERED DYNAMICS EXPLORER AND TETHERED ATMOSPHERIC PROBE - A LOW-COST, LOW-RISK TETHERED SATELLITE PROGRAM**  
R. DELOACH, G. WOOD, K. CRUMBLY (NASA, Langley Research Center, Hampton, VA), C. RUPP, and J. HARRISON (NASA, Marshall Space Flight Center, Huntsville, AL) IN: International

Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 115-118. refs  
(AIAA PAPER 89-1563) Copyright

A tethered satellite flight program to test theoretical studies of tether concepts is proposed. The program consists of multiple flights of an ELV such as the Delta II, using the Small Expendable Deployment System (SEDS) to deploy two instrumented satellite payloads, the Tethered Dynamics Explorer (TDE) and the Tethered Atmospheric Probe (TAP). The applications and characteristics of the TDE and the TAP are described, including verification of the SEDS, the validation of the dynamics and control model for low-tension deployment and the force and moment instrumentation, the demonstration of tether initiated reentry, the collection of in-situ atmospheric and aerothermodynamic data, and the study of long-term tether exposure. R.B.

#### A89-40194#

**TETHER DEORBIT SYSTEM - A PROMISING ALTERNATIVE**  
FRANCO BEVILACQUA and MARIO LORENZO BURIGO (Aeritalia S.p.A, Settore Spazio, Turin, Italy) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 119-126. refs  
(AIAA PAPER 89-1564) Copyright

Possible alternatives to the Space Shuttle for deorbit material from the Space Station are examined, including a disposable tether system, a reusable tether system, an elevator-based tether system, an OMV-based system, and a specially-suited deorbit vehicle. The deorbit maneuver requirements are presented and the options for a deorbit system are compared for the task of putting 16 tons/yr in a reentry trajectory. It is found that the tether deorbit systems have the advantage of less mass than conventional deorbit systems. An additional advantage is the fact that the deorbit maneuver conducted by the tether systems is not affected by the mass distribution inside the capsule. R.B.

#### A89-40195#

**THE IMPACT OF TETHERS ON ATMOSPHERIC SCIENCE**  
JACK W. SLOWEY (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 127-129. refs  
(AIAA PAPER 89-1565)

The use of tethered probes to perform in situ studies of the dynamics of the lower thermosphere is examined. The basic concept of tether probes for studying the thermosphere-ionosphere-magnetosphere system is discussed. Consideration is given to the information which could be gained from using of tethers to study tidal structure, wind structure, turbulence and mass transport, and the wave structure in the upper atmosphere. R.B.

#### A89-40196#

**ATMOSPHERIC DENSITY VARIATIONS VIA TETHERED SATELLITE DRAG**  
GORDON GULLAHORN (Smithsonian Astrophysical Observatory, Cambridge, MA) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 130-135. refs  
(AIAA PAPER 89-1566)

There is little in situ data for the lower thermosphere. The second Tethered Satellite System mission in the mid 1990s will place a satellite within this region at about 130 km altitude. Data from accelerometers to be provided by NASA may allow the recovery of the neutral density profile along the flight path with a sensitivity of better than 10 percent of the ambient density. Simple

estimates of the direct drag-induced acceleration fluctuations are provided and compared with accelerometer sensitivity. Effects of tether dynamics are also examined: lateral modes excited by drag variations both on the satellite and on the tether itself are shown to have small effect compared to the direct accelerations. Equations are provided for future study of the interaction of satellite rotation with longitudinal tether modes. Author

#### A89-40197#

##### **ION COMPOSITION DOWN TO 130 KM - FROM ATMOSPHERIC EXPLORER C TO TSS-2**

JOHN H. HOFFMAN (Texas, University, Richardson) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 136-140. refs  
(AIAA PAPER 89-1567) Copyright

This paper presents results from the ion mass spectrometer on the Atmospheric Explorer-C on composition of the ionosphere down to 129 km, the lowest perigee altitude attained by the spacecraft. The dominant peaks were due to ambient O(+), NO(+), and O2(+). However, there was a large peak at 23 amu from sodium ions that were released (sputtered) from the entrance electrodes of the instrument by the bombardment of ambient N2 molecules. The instrument performed satisfactorily down to the 130 km altitude range. However, suggestions for design improvements, such as increased mass resolution and better venting of the mass analyzer, are given for an instrument that would be suitable for the Tethered Satellite System-2 spacecraft. Author

#### A89-40198\*#

National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, AL.

**TETHERED SATELLITE SYSTEM CONTROL SYSTEM DESIGN**  
DONALD D. TOMLIN, DAVID K. MOWERY (NASA, Marshall Space Flight Center, Huntsville, AL), and CARL S. BODLEY (Martin Marietta Corp., Aerospace Group, Denver, CO) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 143-152.  
(AIAA PAPER 89-1568) Copyright

This paper discusses the control aspects of the Tethered Satellite System mission. The deployer controls system uses length-error and tension-error feedback to control in-plane libration, length, and length rate. The satellite's reaction control system is used to augment tether tension, control rates and attitude about the tether axis, and to damp in-plane and out-of-plane libration. The orbiter's reaction control system is also used to control in-plane and out-of-plane libration. Results of simulations are presented for the flight portion of the Tethered Satellite System mission. Author

#### A89-40199#

##### **THREE-DIMENSIONAL VIBRATIONS OF TETHERED SATELLITE SYSTEM**

MARCELLO PIGNATARO (Roma I, Università, Rome, Italy), ANGELO LUONGO (L'Aquila, Università, Italy), and MONICA PASCA IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 153-161. refs  
(AIAA PAPER 89-1569) Copyright

An analytical model is presented to study the three-dimensional free vibrations of the Tethered Satellite System. In the model, the tether is considered as an elastic continuum with mass, while the Space Shuttle and the subsatellite are considered as two concentrated masses. Linearized equations of motion are given for out-of-plane and in-plane vibrations. Extended numerical analyses are performed for the geometrical and mechanical properties of the system. It is found that the two in-plane motion components are weakly coupled through the gyroscopic forces,



## 15 MISSIONS, TETHERS, AND PLATFORMS

with generally transversal or longitudinal type modes. The transversal modes are almost identical to the out-of-planes modes.

R.B.

### AB9-40200#

#### A LENGTH RATE CONTROL LAW APPLICABLE TO SPACE STATION TETHER DEPLOYMENT/RETRIEVAL

JOHN R. GLAISE (Control Dynamics Co., Huntsville, AL) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 162-165. (AIAA PAPER 89-1570) Copyright

Consideration is given to a passive control law for Space Station tether deployment and retrieval, based on the control of tether rate instead of tension. A design model is developed for a system consisting of point end masses and a straight, inextensible tether of nonnegligible mass, moving in a nearly circular orbit. The model is used to determine limits on control gains and deployment angles and to characterize the effects of the motor and deployer on performance. The performance of the control law is validated with a tethered satellite simulation program.

R.B.

### AB9-40201#

#### SPACE STATION BASED TETHERED PAYLOAD - CONTROL STRATEGIES AND THEIR RELATIVE MERITS

P. K. LAKSHMANAN, V. J. MODI, and A. K. MISRA (British Columbia, University, Vancouver, Canada) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 166-177. refs (Contract NSERC-A-2181) (AIAA PAPER 89-1571) Copyright

A mathematical model is proposed here for studying the dynamics of the Tethered Satellite System (TSS) that consists of a plate-type Space Station from which a tether supported subsatellite is deployed or retrieved. The rigid body dynamics of the tether, subsatellite and Space Station are analyzed accounting for the mass of the tether as well as a three dimensional offset of its point of attachment. Controllability of the linearized equations is established numerically and a comparative study of three different controls strategies conducted. The strategies employ thrusters, tension in the tether line or motion of the offset of the attachment to achieve control of the system subjected to a relatively large initial disturbance. Results suggest that, in the stationkeeping mode, the tension control strategy damps a given disturbance in the shortest time, however, at an expense of the energy. On the other hand, the offset control proves to be the most efficient in terms of energy consumption, but now the response to disturbance persists over a long duration. In addition, the performance of the thruster control, tension control, and offset control strategies, as well as their combinations are analyzed during retrieval of the tether. Results suggest that the thruster-offset hybrid controller is most effective in damping out given disturbances.

Author

### AB9-40202#

#### ORBIT EVOLUTION AND DECAY OF TETHER LAUNCHED SPACE SYSTEMS

S. BERGAMASCHI (Padova, Università, Padua, Italy) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 178-183. refs (Contract CNR-PSN-87-002) (AIAA PAPER 89-1572) Copyright

An approximate analytical method is used to determine the orbital lifetime of tethered or tether-launched passive spacecraft orbiting in a planetary atmosphere. The method is used to investigate the problems of a TSS-1 free decaying orbit after tether breakage, waste disposal from the Space Station, and monitoring of the Martian atmosphere. Small variations of tether length are shown to cause large changes in lifetime values.

R.B.

### AB9-40203#

#### DYNAMICS AND CONTROL OF TETHERED ANTENNAS/REFLECTORS IN ORBIT

LIANGDONG LIU and PETER M. BAINUM (Howard University, Washington, DC) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 184-193. refs

(Contract F49620-89-C-0002)

(AIAA PAPER 89-1573) Copyright

The system linear equations for the motion of a tethered shallow spherical shell in orbit with its symmetry axis nominally following the local vertical are developed. The shell roll, yaw, tether out-of-plane swing motion and elastic vibrations are decoupled from the shell and tether in-plane pitch motions and elastic vibrations. The neutral gravity stability conditions for the special case of a constant length rigid tether are given for in-plane motion and out-of-plane motion. It is proved that the in-plane motion of the system could be asymptotically stable based on Rupp's tension control law, for a variable length tether. However, the system simulation results indicate that the transient responses can be improved significantly, especially for the damping of the tether and shell pitch motion, by an optimal feedback control law for the rigid variable length tether model. It is also seen that the system could be unstable when the effect of tether flexibility is included if the control gains are not chosen carefully. The transient responses for three different tension control laws are compared during typical station keeping operations.

Author

### AB9-40204#

#### GENERAL 3-D ANIMATION TECHNIQUES FOR TETHER DYNAMICS

DAVID D. LANG (David D. Lang Associates, Mercer Island, WA) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 194-199. (AIAA PAPER 89-1574) Copyright

The paper presents general as well as specific information about an approach to engineering tether dynamics animation as applied to the Generalized Tethered Object Simulation System (GTOS). The discussion relates to cost effective hardware and software solutions only recently available to the engineering community. First, the elements of the new field of desk top video production are described. Then a discussion of hardware and software needed to create three dimensional animated depictions of solutions to tether dynamics problems is presented. The animation modeling is described with emphasis on the generality of the technique to all tether simulations. Finally, interface requirements between an arbitrary tether simulation and the desktop animation system is discussed.

Author

### AB9-40205\*# Stanford Univ., CA.

#### EXPERIMENTS WITH THE KITE ATTITUDE CONTROL SIMULATOR

J. DAVID POWELL (Stanford University, CA) and ROBERT KLINE-SCHODER IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 205-214. refs

(Contract NCC2-389)

(AIAA PAPER 89-1576) Copyright

Simulation experiments are conducted to test an attitude control technique for tethered satellites using the tether tension force to generate control torques by moving the tether attach point relative to the satellite center of mass. A scaled, one-dimensional, air-bearing supported laboratory simulation of the Kinetic Isolation Tether Experiment shows that the attitude of the simulator can be regulated to within 0.75 arcsec with a bandwidth of about 0.1 Hz. The control design includes a state estimator to calculate the vehicle mass center and to calculate the effect of the stepper

motor dynamics on the state estimate. Results are presented from closed-loop attitude control experiments to verify the attitude control technique. R.B.

#### AB9-40206#

##### ANALYSIS OF A TETHERED STABILIZED SCHMIDT TELESCOPE ASSIGNED TO THE SPACE STATION

F. BERTOLA, P. RAFANELLI, F. ANGRILLI, G. BIANCHINI, R. DA FORNO (Padova, Università, Padua, Italy) et al. IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 215-223. refs (AIAA PAPER 89-1577) Copyright

The concept of a Schmidt telescope connected to the Space Station by a 2-10 km long tether is discussed. A mission scenario and the optical characteristics of the telescope are described. A linearized mathematical model is used to study the dynamic behavior of the telescope platform in space. Simulations are conducted to account for environmental perturbations, thermal effects, atmospheric drag, micrometeor impact, and the dynamical response to slewing motion. R.B.

#### AB9-40207#

##### THE OUTPOST PLATFORM - A TRANSPORTATION AND SERVICE PLATFORM IN LOW EARTH ORBIT

THOMAS C. TAYLOR, CHARLES W. COOK, and WILLIAM A. GOOD (Global Outpost, Inc., Alexandria, VA) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 224-233. refs (AIAA PAPER 89-1578) Copyright

The Outpost concept, a LEO platform derived from the external tank of the Space Shuttle, is discussed. By using tethers, the Outpost is capable of evolving to a transportation-related commercial operation in orbit. Commercial tether services and disposable tether experiments are reviewed. The small disposable tethers and tether subsystems on the Outpost platform are illustrated. R.B.

#### AB9-40208#

##### THE SCIENCE AND APPLICATION TETHERED PLATFORM

FABRIZIO LUCCHETTI and PIETRO MERLINA (Aeritalia S.p.A., Settore Spazio, Turin, Italy) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 234-240. refs (AIAA PAPER 89-1579) Copyright

The Science and Application Tethered Platform (SATP), a large, multistation platform suspended at the end of a tether attached to the Space Station, is discussed. The SATP operations, configuration, structure, attitude measurement and control system, auxiliary propulsion system, thermal control, power, communication, and data handling are described. A functional drawing of the complex tether is presented and briefly discussed. C.D.

#### AB9-40209# University of Central Florida, Orlando.

##### A DESIGN FOR A SPACE STATION TETHERED ELEVATOR

MICHAEL H. HADDOCK and LOREN A. ANDERSON (Central Florida, University, Orlando, FL) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 241-248. Research supported by the Universities Space Research Association and NASA. refs (AIAA PAPER 89-1580) Copyright

The preliminary design of a structure capable of providing transportation, remote servicing, and access to residual gravity levels between the Space Station and a tethered mass is described. The mobile structure, or elevator, operates on a 10 kilometer tether attached to the Space Station structure at one end and a tethered

mass at the opposite end. The elevator can be attached to, or detached from the tether with use of Space Station robotics or a Space Shuttle's remote manipulator system. The paper discusses the potential uses, preliminary objectives, and parameters for the elevator design. Based on these parameters, the elevator's structural configuration is described. Three major elevator subsystems are addressed. First, the design of a robotic implement, attached to the elevator, is proposed for performing various tasks on tethered platforms and aiding in hooking the elevator to a tether. Second, the design of a drive mechanism used to carry out interfaces between a tether and the elevator is cited. Third, the design of a self-sufficient power generation and transmission system for the elevator is presented. Author

#### AB9-40210#

##### TETHERED GRAVITY LABORATORIES STUDY - THE CENTER-OF-GRAVITY MANAGEMENT CONCEPT

FRANCO BEVILACQUA, PIETRO MERLINA (Aeritalia S.p.A., Settore Spazio, Turin, Italy), ENRICO CARLO LORENZINI, MARIO COSMO (Smithsonian Astrophysical Observatory, Cambridge, MA), and SILVIO BERGAMASCHI (Padova, Università, Padua, Italy) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 249-262. refs (AIAA PAPER 89-1581) Copyright

A tether system deployed from the Space Station (SS) can provide a facility for controlling the vertical position of the system center of mass at low frequencies or in the dc mode. A review of the force field on board the SS is presented, and a classification is given of the sources of external perturbations modifying the g-field at the microgravity laboratory. This provides a set of constraints to be taken into account. A complete analysis of possible configurations (single tether system, double tether system) is performed, including design criteria, SS impacts, and configuration tradeoff. Basic results are presented from an analysis aimed at identifying the acceleration noise level transmitted to the SS when a tethered system is acted upon by environmental perturbations. Possible benefits achievable by implementing the center-of-gravity management concept are assessed on the basis of development risks and expected hardware complexity. C.D.

#### AB9-40212#

##### TETHERED SATELLITE SYSTEM - ELECTROMAGNETIC FIELD AND RAM EFFECT NUMERICAL SIMULATION IN NEAR PROXIMITY OF TSS SATELLITE

A. LORENZONI (Agenzia Spaziale Italiana, Rome, Italy) and E. PIERAGOSTINI (Telespazio S.p.A., Rome, Italy) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 271-273. (AIAA PAPER 89-1583) Copyright

Two tethered satellite/environment configurations are simulated using computer codes and FEMs. The geometric model used for this simulation is described. Software applicable for real-time evaluations and computer codes for various simulated satellite/environment scenarios are presented. It is noted that the current computer codes permit low cost and short time analysis of physical and chemical conditions near conductive bodies; the software is applicable for improving the accuracy of electronic density and equivalent plasma temperature probes; and the use of single subroutines to simulate physical and chemical phenomena needs to be investigated. I.F.

#### AB9-40214#

##### TETHER AS UPPER STAGE FOR LAUNCH TO ORBIT

BRIAN TILLOTSON (Space Research Associates, Inc., Bellevue, WA) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 283-287. (AIAA PAPER 89-1585) Copyright

## 15 MISSIONS, TETHERS, AND PLATFORMS

An orbiting tether may act as a low-cost reusable upper stage in a system for launch to LEO or GEO, providing large velocity changes (at least 1 km/s) to a payload. We describe the requirements for such a tether and discuss how these requirements affect the tether design, particularly the need for a modular design using many identical components. The performance and utility of gravity gradient stable tethers, rotating skyhook tethers, and multi-stage tethers are compared. The multi-stage rotating tether is a new configuration which we describe and discuss. It offers superior performance and versatility as compensation for its complex dynamics. Author

**A89-40215#**

### ON THE TILTING CRANE CONCEPT

F. VENDITTI (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands), G. ORIGGI, and A. ERCOLI FINZI (Milano, Politecnico, Milan, Italy) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 288-297. refs

(AIAA PAPER 89-1586) Copyright

The characteristics and feasibility of a 'tilting crane' concept for tethered systems which involves the transfer of payloads between different LEOs are discussed. The transfer of a payload attached to one of the end bodies is demonstrated via an overturn of the system. In the method, the in-plane libration motion is excited, with appropriate changes in tether length. The concept is demonstrated with the example of a reusable system for moving payloads between a space station orbit and a lower orbit with an apogee of about 250 km. R.R.

**A89-40216#** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

### TRANSPORTATION USING SPINNING TETHERS WITH EMPHASIS ON PHASING AND PLANE CHANGE

DAVID G. HENDERSON (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 298-305. refs

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This paper studies the potential uses of spinning tethers as components in a transportation system. Additional degrees of freedom in the selection of transfer orbits as well as phasing control are introduced by allowing both the spin rate of the tethers to be controllable and by allowing the ejection and capture points to be anywhere along the tether length. Equations are derived for the phasing of the planar transfer problem. A construction algorithm for nonplanar transfers is developed and nonplanar phasing conditions are examined. Author

**A89-40217#** Aeritalia S.p.A., Turin (Italy).

### HOW TETHERED SYSTEMS CAN BENEFIT MICROGRAVITY RESEARCH IN THE SPACE STATION ERA

MARIA STELLA LAVITOLA, FRANCESCO GIANI, and MAURO BRICCARIELLO (Aeritalia S.p.A., Settore Spazio, Turin, Italy) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 309-315. refs

(Contract NAS9-17877)

(AIAA PAPER 89-1588) Copyright

The use of a tethered movable orbiting laboratory for microgravity research is examined. The relation between reduced microgravity carriers and acceleration levels, and the effects of acceleration levels on in-orbit experiments are studied. The tuning of the gravity level at a space laboratory by employing a tether is described. The applications of the variable gravity environment to research in fluids and materials sciences, life sciences, separative techniques, and physical and applied chemistry are discussed. I.F.

**A89-40218#** National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, AL.

### AN ARTIFICIAL GRAVITY DEMONSTRATION EXPERIMENT

C. RIIPP (NASA, Marshall Space Flight Center, Huntsville, AL), L. LEMKE (NASA, Ames Research Center, Moffett Field, CA), and P. PENZO (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 316-322.

(AIAA PAPER 89-1589)

An artificial gravity experiment which is tethered to a Delta second stage and which uses the Small Expendable Deployer System is proposed. Following tether deployment, the Delta vehicle performs the required spin-up maneuver and can then be passivated. A surplus reentry vehicle houses the artificial gravity life science experiments. When the experiments are completed, the reentry phase of the experiment is initiated by synchronizing the spin of the configuration with the required deorbit impulse. R.R.

**A89-40219#** Naples Univ. (Italy).

### ATTITUDE DYNAMICS OF THE TETHER ELEVATOR/CRAWLER SYSTEM FOR MICRO-GRAVITY APPLICATIONS

S. VETRELLA, A. MOCCIA (Napoli, Università, Naples, Italy), E. C. LORENZINI, and M. COSMO (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 323-330. Research supported by the Agenzia Spaziale Italiana and MPI. refs

(Contract NAS6-36606)

(AIAA PAPER 89-1590) Copyright

The Tether Elevator/Crawler System (TECS) consists of two end platforms tethered to opposite sides of the Space Station. A variable gravity laboratory is located on board an elevator which can crawl along the upper tether. This paper analyzes the elevator's attitude dynamics in order to evaluate its effect on microgravity applications. To this end, a simulation model is described and numerical results are given for a steady state case. It is shown that the elevator attitude dynamics, without attitude control, contributes additional spectral lines to the acceleration noise. Author

**A89-40220#**

### ADVANCES IN SPACE TETHER MATERIALS

RALPH F. ORBAN (Fiber Materials, Inc., Space Technology Div., Columbus, OH) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 333-338.

(AIAA PAPER 89-1591) Copyright

Space tether systems built with metal-coated Kevlar are discussed. The processing of metal-coated Kevlar and process improvements are reviewed, and prototype tether constructions are described. Results of tests involving electrical resistance measurements, SEM examination, and exposure to an oxygen plasma to simulate exposure to atomic oxygen are reported. C.D.

**A89-40222#**

### GRAVITY GRADIENT DISTURBANCES ON ROTATING TETHERED SYSTEMS IN CIRCULAR ORBIT

ANTHONY B. DECOU (Northern Arizona University, Flagstaff) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 343-351.

(AIAA PAPER 89-1593) Copyright

In the presence of gravity, an orbiting system of point masses



connected by tethers and rotating about its center of mass in a plane with arbitrary orientation will be perturbed by gravity gradient effects in such a way that the masses will deviate from the system plane of rotation and the rate of rotation will deviate from its average value. The amount of these deviations are calculated as functions of time for circular orbits in a  $1/R$ -squared gravity field assuming that the tethers are massless and have fixed length. Three system geometries are treated in detail: the rotating dumbbell with equal or unequal masses, two equal masses rotating around an arbitrary mass midway between and connected by two equal length tethers, and a rotating equilateral triangle with equal masses at the corners connected by tethers along the sides. Author

**AB9-40224#**

**MECHANICAL AND THERMIC PROPERTIES FOR EVALUATION OF TSS-1 TETHER DYNAMIC BEHAVIOR**  
F. ANGRILLI, G. BIANCHINI, M. DA LIO, and G. FANTI (Padova, Università, Padua, Italy) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 361-369. Research supported by CNR and Agenzia Spaziale Italiana. refs

(AIAA PAPER 89-1595) Copyright

This paper presents the first results of a study on the mechanical and thermic properties of the tether to be used in TSS-1 missions. Stiffness, hysteresis, loss factor and propagation velocity of longitudinal waves at different temperatures ( $-100 + +80$  C) were measured and results interpreted. On the basis of the experimental results, assuming some simplified work hypotheses, a physical model which presumes the distribution of total load among tether components is proposed, and a mathematical model of a two-layer tether has been developed. Author

**AB9-40225#**

**THE USE OF TETHERED SATELLITES FOR THE COLLECTION OF COSMIC DUST AND THE SAMPLING OF MAN-MADE ORBITAL DEBRIS FAR FROM THE SPACE SHUTTLE AND SPACE STATION**

G. J. CORSO (Loyola University, Chicago, IL) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 370, 371. refs

(AIAA PAPER 89-1596) Copyright

The application of tethered satellites to the collection of cosmic dust particles and the monitoring of orbital debris is examined. The various types of cosmic dust particles that enter the earth's atmosphere are described. The difficulties associated with collecting cosmic particles using high-altitude balloons and U-2 type aircraft are discussed. The usefulness of satellites for collecting uncontaminated particles in the 110-130 km altitude range is noted. I.F.

**AB9-40226#** National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, TX.

**OPERATIONAL COMPLEXITIES OF REAL TETHER SYSTEMS IN SPACE**

JEFFREY A. HOFFMAN (NASA, Johnson Space Center, Houston, TX) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 381-385.

(AIAA PAPER 89-1598) Copyright

Some of the major operational concerns that have to be addressed in planning a real tether mission, such as the TTS-1 mission, which is due to fly on the Space Shuttle in the early 1990's, are discussed. Specifically, several operational hazards, such as the tether reel overtorque and the loss of tether system control, are considered from the viewpoint of flight crew, who must be able to detect the presence of a problem and to determine the corrective action to be taken. Various safety measures are discussed. I.F.

**AB9-40227#**

**TETHER INSPECTION AND REPAIR - THE KEY FOR THE DEVELOPMENT OF PERMANENT TETHERED FACILITIES**  
SALVATORE CLARDO, FRANCO BEVILACQUA (Aeritalia S.p.A., Settore Spazio, Turin, Italy), and SERGIO BERETTA (Società Cavi Pirelli S.p.A., Milan, Italy) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 386-400. Research sponsored by the Agenzia Spaziale Italiana. refs

(AIAA PAPER 89-1599) Copyright

The most promising manufacturing techniques for arriving at the optimum configuration of a multifunction, long-duration tether are investigated along with the most suitable techniques for in-orbit inspection and repair activities. Particular emphasis is given to the problem of micrometeoroid/debris protection. The option of using a crawling device to carry inspection and repair tools is addressed, taking into account the additional requirements that this would impose on the tether design. C.D.

**AB9-40228#**

**SATELLITE-TETHERED UPPER-ATMOSPHERIC RESEARCH FACILITY**

CYRUS L. BUTNER and CHARLES F. GARTRELL (General Research Corp., McLean, VA) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 410-413. refs

(AIAA PAPER 89-1607) Copyright

This paper describes the user applications and requirements for a Satellite-tethered Upper-atmospheric Research Facility (SURF), along with its conceptual design and potential operations. Potential design and operational concerns are also addressed. Although a variety of tether systems have already been proposed for a wide range of applications in earth orbit, the SURF represents a new approach to tether operations in low earth orbit (LEO) and, in particular, the upper atmosphere. This document represents an expanded abstract for the paper that will be presented at the Third International Conference on Tethers in Space in San Francisco, California. Author

**AB9-40229#**

**MATERIAL TRANSPORT BETWEEN LEO AND THE MOON USING TETHERS**

MARTIN O. STERN and JAMES R. ARNOLD (California, University, La Jolla) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 421-424. refs

(AIAA PAPER 89-1614) Copyright

The use of tether configurations to transport materials between LEO and the lunar surface is evaluated. A transportation model and an evaluation model are employed to evaluate the configurations. The mission objective is to transport a fixed yearly quantity of lunar material from the lunar surface back to LEO. The proposed designs for the five tether configurations are described. The use of ballast to maintain the balance of the station and the effects of ballast on the performance of the tether designs are examined. The mass payback ratios for the five configurations are compared. It is determined that the spinning tether configuration which is proposed to use a tether of about three times greater breaking strength than any material currently available is the most cost effective. I.F.

**AB9-41038#**

**TETHER INITIATED SPACE RECOVERY SYSTEM (TISRS) - ITALIAN ACTIVITIES TOWARD FLIGHT DEMONSTRATION**

MARIO LORENZO BURIGO and PIETRO MERLINA (Aeritalia S.p.A., Settore Spazio, Turin, Italy) AIAA, NASA, Agenzia Spaziale Italiana, and ESA, International Conference on Tethers in Space -

## 15 MISSIONS, TETHERS, AND PLATFORMS

Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989. 7 p. (AIAA PAPER 89-1602)

The proposed flight demonstration of the TISRS for deorbiting is discussed. A diagram of the deorbit concept and a list of the systems needed for the TISRS flight demonstration are given. The objectives of the TISRS flight demonstration are described.

I.F.

**A89-41040\*** Anco Engineers, Inc., Culver City, CA.

### DEVELOPMENT OF A TETHER DEPLOYMENT MONITORING SYSTEM

P. IBANEZ, F. J. GRAY, and A. G. LEVI (ANCO Engineers, Inc., Culver City, CA) AIAA, NASA, Agenzia Spaziale Italiana, and ESA, International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989. 6 p. Research supported NASA.

(AIAA PAPER 89-1616)

The feasibility of monitoring the position of a tether during orbital deployment is discussed. Attention is given to the techniques for attaching reflectors to the tether at periodic intervals during the deployment process, which could then be tracked visually or with a radar unit that is pointed towards the targets by the control system. Consideration is also given to a method for tether attitude and tension detection, and a launching device to attach small instrumentation platforms onto the tether during deployment. The configuration of a tether deployment monitoring system (TEDEMS) and the equipment developed to perform the above tasks are described, along with an analysis of requirements for the construction of a family of space-borne TEDEMS suitable for use on the Space Shuttle, Expendable Launch Vehicles, or the Space Station. The potential uses of the TEDEMS for launching small tether-borne experimental packages are discussed. Design and block diagrams are included.

I.S.

**A89-43326\*** Consiglio Nazionale delle Ricerche, Rome (Italy). **SPACE TETHERS FOR SCIENCE IN THE SPACE STATION ERA; PROCEEDINGS OF THE SECOND INTERNATIONAL CONFERENCE, VENICE, ITALY, OCT. 4-8, 1987**

LUCIANO GUERRIERO, ED. (CNR, Piano Spaziale Nazionale, Rome, Italy) and IVAN BEKEY, ED. (NASA, Washington, DC) Conference sponsored by CNR, NASA, ESA, et al. Bologna, Societa Italiana di Fisica (Societa Italiana di Fisica, Conference Proceedings, Volume 14), 1988, 678 p. For individual items see A89-43327 to A89-43407.

Copyright

Various papers on space tethers are presented. The general topics addressed include: the space program context for tethers, early experimental validation of tethers, tether dynamics simulations, electrodynamic aspects of tethers, and tethers for science and innovative uses. Also considered are: tethers in space, tether dynamics, tethers on stations and platforms, and tether technology.

C.D.

**A89-43327**

### TETHER HISTORY AND HISTORIOGRAPHY

MARIO D. GROSSI (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 3-8. refs

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The highlights of the origins and development of spaceborne tethers are reviewed. Special emphasis is given to R&D activity carried out at SAO. The areas of investigation addressed include tether feasibility, tether dynamics, tether electrodynamic, and tether constellations.

C.D.

**A89-43328**

### TETHER PROGRAMS

GIANFRANCO MANARINI (CNR, Piano Spaziale Nazionale, Rome, Italy) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy,

Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 9-13. Copyright

Scientific, mission/operations, and technological applications of the space tether concept are discussed. Applications in electrodynamic and space plasma physics, astrophysics research and X-ray astronomy, atmospheric studies, terrestrial physics, microgravity, ULF/ELF/VLF wave propagation, energy conversion, docking of tethered systems, artificial gravity generation, space recovery, and tethered waste disposal are summarized, and an application to gravity gradient stabilization is examined in some detail. Technological applications to tether damping, simplified tether system elements and missions, tether-based attitude control system, outer atmospheric research for science engineering, and tether maintenance, refurbishment, and repair systems are addressed. Programmatic strategy considerations are discussed.

C.D.

**A89-43329\*** National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, AL.

### STATUS OF TETHERED SATELLITE SYSTEM (TSS) DEVELOPMENT

JAY H. LAUE (NASA, Marshall Space Flight Center, Huntsville, AL) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 14-25. refs

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The Tethered Satellite System (TSS) is a cooperative space system and science development activity being carried out by the U.S. and Italy. The TSS will involve an instrument-laden satellite that can be deployed from the cargo bay of the Shuttle Orbiter using a long tether to altitudes both above and below that of the Orbiter. This paper discusses the predevelopment activities, development approach and management relationships, current hardware and software designs and interfaces, overall science experiment status and plans, and mission operation planning for the first TSS mission.

C.D.

**A89-43330**

### TETHER TUTORIAL

DAVID A. ARNOLD (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 26-36.

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The behavior of satellites connected by long tethers is discussed in terms of basic physical principles with some mathematics included. The topics included the gravitational, centrifugal, and aerodynamic forces on the system, vertical stabilization using the gravity gradient force, librations of the system, and longitudinal and transverse motions of the tether. Deployment and retrieval of the system are discussed, along with strategies for controlling oscillations particularly during retrieval. Other topics include the use of tethers for exchanging energy and momentum between satellites, tether strength requirements and tapering techniques in long or rotating systems.

Author

**A89-43331\*** National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, AL.

### EARLY TETHER DYNAMICS FLIGHT EXPERIMENTS

CHARLES C. RUPP (NASA, Marshall Space Flight Center, Huntsville, AL) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 39-42.

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This paper proposes an evolutionary series of tether-dynamics flight experiments using the Small Expendable Deployer System (SEDS). Such experiments could be launched as secondary payloads on the Delta ELV. The purpose of the series of experiments is to acquire data on tether deployment rate, tension, tether shape, and operating environment to compared with

computer-based tether simulations. A second purpose is to serve as a precursor for the Orbiter-based SEDS, since both the tether deployer and the flight profile are similar. Additional flights could observe tether dynamics over a much wider range of operational and environmental conditions and could employ more comprehensive measurements. Author

**AB9-43332\*** Energy Science Labs., Inc., San Diego, CA.  
**THE SMALL EXPENDABLE DEPLOYMENT SYSTEM (SEDS)**

JOSEPH A. CARROLL (Energy Science Laboratories, Inc., San Diego, CA) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 43-50.

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A Small Expendable-tether Deployment System (SEDS) has been developed for use with the Space Shuttle, expendable launch vehicles, and the Space Station. The basic SEDS concept and work done on it to date are reviewed. Control issues, the advantages and disadvantages of this deployment concept, some generic tether safety issues, simulation programs, and testing are described. Potential SEDS applications are reviewed. C.D.

**AB9-43333\*** Auburn Univ., AL.

**GET-AWAY TETHER EXPERIMENT - EXPERIMENTAL PLANS**

MICHAEL GREENE, JUSTIN WALLS, J. THERON CARTER (Auburn University, AL), and CHARLES C. RUPP (NASA, Marshall Space Flight Center, Huntsville, AL) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 51-60. refs

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The experimental capabilities of the Get-Away Tether Experiment (GATE) are presented and a series of demonstration mission are proposed. The GATE is a free-flying tether system that will develop or demonstrate technology in the areas of tether dynamics (deployment and stabilization, retrieval, stationkeeping, and severance), tether electrodynamic, micrometeor hazards to tethers, and disturbance rejection. The system consists of two subsatellites connected by 1 km of tether. The free-flying system is ejected from the Orbiter via a Getaway Special (GAS) canister. Two dynamics missions are profiled along with a description of electrodynamic mission capabilities. The dynamic interactions of the end body and tether may be observed from the Orbiter or from an on-board video tracking system. Hence, GATE provides a unique, low cost capability to demonstrate various tether technologies, and address critical design and safety issues associated with future tether applications. An assessment of the significant measurable parameters and associated instrumentation is given. Future work and system development projection schedules are also outlined. Author

**AB9-43334\*** Stanford Univ., CA.

**RECENT LABORATORY RESULTS OF THE KITE ATTITUDE DYNAMICS SIMULATOR**

ROBERT KLINE-SCHODER and J. DAVID POWELL (Stanford University, CA) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 61-66.

(Contract NCC2-389)

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It has previously been shown that, for all but the most simple tethered satellite missions, conventional means of performing attitude control are insufficient. A particularly effective method of implementing attitude control for tethered satellites is to use the tether tension force to generate control torques by moving the tether attach point relative to the satellite center of mass. It has been proposed to demonstrate this attitude control technique in a Space Shuttle flight test project known as the Kinetic Isolation Tether Experiment (KITE). This paper describes a scaled, one dimensional laboratory simulation of the KITE mission. The simulator has been built to verify theoretical predictions of attitude

control ability and to investigate the technological requirements in order to implement this concept. The laboratory apparatus is described in detail and preliminary experimental results are presented and discussed. The results to date have shown a fine pointing accuracy of 5 arc-seconds RMS and a closed-loop bandwidth  $c/0.06$  Hz. Author

**AB9-43336**

**VALIDATION OF TETHERED PACKAGE DEPLOYMENT FOR THE SPACE STATION**

RICHARD S. POST, JAMES D. SULLIVAN, JAMES H. IRBY (MIT, Cambridge, MA), and ENRICO C. LORENZINI (Smithsonian Astrophysical Observatory, Cambridge, MA) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 73-75.

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The dynamics of deployment and retrieval maneuvers of a tethered package in the region about the Space Station can be validated by deploying a simple 'golf ball' packaged on a fiber optic cable from the Space Shuttle. Strategies for casting the package in any given direction from the Shuttle are discussed and fast, impulsive retrieval maneuvers with negligible tension in the tether are described. A preliminary design for the subsystems necessary for spin-casting, tracking, and recovery of the 'golf ball' are also presented. C.D.

**AB9-43337\*** Utah State Univ., Logan.

**FURTHER ANALYSIS OF THE RESULTS FROM A SERIES OF TETHERED ROCKET EXPERIMENTS**

N. KAWASHIMA, S. SASAKI, K.-I. OYAMA (Institute of Space and Astronautical Science, Tokyo, Japan), W. J. RAITT (Utah State University, Logan), P. R. WILLIAMSON (Stanford University, CA) et al. IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 76-81. refs

(Contract NAGW-235)

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The data obtained in the most recent Japan-US tether rocket experiment CHARGE 2 have been further analyzed. The interaction of the moving tether system across the geomagnetic field with the ionospheric plasma can be explained by a simple model of the current through a plasma. The response of the tether system when a high voltage is applied is studied and 500 volts could be applied without any appreciable discharge. The detected signal of the wave excited by an application of high voltage between the mother and daughter rocket and by a pulse modulated electron beam is also studied. Author

**AB9-43338**

**OPTIMAL STATE ESTIMATION OF A TETHERED SATELLITE SYSTEM**

ROBERT F. STENGEL (Princeton University, NJ) and DANIEL S. SWANSON IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 85-92. refs

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This paper investigates the use of the hybrid Kalman filter to generate a minimum-variance estimate of the state of a tethered satellite system using only noisy sampled-data measurements, a model of the system dynamics, and a model of the measurement process. The filter equations are stated and discussed. Equations for the system dynamics and measurement process are developed. Simulated flight data is passed through the filter, generating an estimate of the system state. Comparing the measurement and estimate errors shows that after a startup period the estimate is better than the measurements. Author

**AB9-43339**

**EFFECT OF TETHER FLEXIBILITY ON THE TETHERED SHUTTLE SUBSATELLITE STABILITY AND CONTROL**



## 15 MISSIONS, TETHERS, AND PLATFORMS

LIANGDONG LIU and PETER M. BAINUM (Howard University, Washington, DC) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 93-103. refs  
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This paper investigates the effect of tether flexibility on the (in-plane) stability regions as a function of tether tension control parameters during stationkeeping. It is found that the size of the stability regions for the flexible tether is reduced considerably as compared with that for the rigid massive tether for some control parameters. An alternate optimal control law, which includes additional feedback of the first vibrational mode and its rate, is introduced; the results of stationkeeping simulations show that the transient responses of both the in-plane swing angle and vibrations are improved as compared with previously developed control laws. For retrieval a typical nonlinear control law which includes the nonlinear feedback of the tether length, in-plane and out-of-plane swing angles and their rates is developed. Simulation results show that the amplitudes of the in-plane and out-of-plane swing angles could be reduced significantly; also it is demonstrated that the amplitudes of the tether vibrational modes should be considered for the selection of the control gains. Author

**A89-43340**

### DYNAMICS AND CONTROL OF TWO SPACE PLATFORMS CONNECTED BY A SHORT TETHER

A. MOCCIA and S. VETRELLA (Napoli, Università, Naples, Italy) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 104-110. Research supported by CNR and MPI. refs  
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The dynamical behavior of a tethered system consisting of two vertically spaced physical antennae carried along parallel paths by the deployer and the subsatellite is analyzed. Special emphasis is given to the analysis of the attitude dynamics of the subsatellite because of its significant effect on the phase difference measurement error. The results show that the low-frequency effects due to in-plane, out-of-plane, and yaw angle oscillations do not affect significantly the image quality and the height measurement error. High-frequency oscillations connected with pitch and roll angles and tether length variations require an adequate control system and/or a sophisticated image preprocessing software. C.D.

### **A89-43341\*** Draper (Charles Stark) Lab., Inc., Cambridge, MA. INTERACTION OF THE SPACE SHUTTLE ON-ORBIT AUTOPILOT WITH TETHER DYNAMICS

EDWARD W. BERGMANN (Charles Stark Draper Laboratory, Inc., Cambridge, MA) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 111-115. (Contract NAS6-36602)  
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The effect of Orbiter flight control on tether dynamics is studied by simulation. Open-loop effects of Orbiter jet firing on tether dynamics are shown, and the potential for closed-loop interaction between tether dynamics and Orbiter flight control is determined. The significance of these effects on Orbiter flight control and tether control is assessed. C.D.

**A89-43342**

### DYNAMICS SIMULATION OF THE TSS ACTIVELY CONTROLLED SATELLITE

F. VENDITTI, B. CIBRARIO, and B. MUSETTI (Aeritalia S.p.A., Gruppo Sistemi Spaziali, Turin, Italy) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 116-129. refs  
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Simulations of the Attitude Measurement and Control Subsystem

(AMCS) of the Tethered Satellite System (TSS) project are discussed. The AMCS is reviewed, including its requirements and operative modes and its functions. The simulation model is described, and a set of simulations describing a complete mission is presented. The results demonstrate the correct control action of the AMCS and the complete attitude dynamics of the satellite. C.D.

**A89-43343**

### OUT-OF-PLANE PERTURBATIONS OF A RESONANT TETHER

JOHN V. BREAKWELL (Stanford University, CA) and JAMES W. GEARHART (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 130-136. Copyright

A tethered satellite in a nonpolar, nonequatorial, circular orbit is made to tumble forward essentially in the orbit plane. The tumbling rate, relative to the local vertical, matches the orbital rate and is controlled only by varying the tether tension. Out-of-plane angular deviations, due to oblateness and the consequent orbit plane precession, are analyzed and shown to remain small. Author

**A89-43344**

### TETHSIM - A DYNAMICS SIMULATION SOFTWARE PACKAGE FOR TETHERED SYSTEM

F. VENDITTI, B. CIBRARIO (Aeritalia S.p.A., Gruppo Sistemi Spaziali, Turin, Italy), and G. ORIGGI (Milano, Politecnico, Milan, Italy) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 137-144. Copyright

This paper presents the description of a dynamics simulation package, called Tethsim, devoted to the investigation of tethered systems behavior in space. The package also analyzes specific problems related to tethered system simulation such as validation, varying-length tether growth model, and CPU time consumption and describes the approaches used to solve them. The system is modeled in Tethsim as composed by rigid bodies and point-masses connected by spring-dashpot, to form an open-line configuration. Strong emphasis has been placed on easing user interfaces with the program; in particular, the software can be flexibly adapted to the specific system to be simulated. Author

**A89-43345**

### EFFECTS OF DAMPING ON TSS-1 VIBRATIONS STABILITY

A. SINOPOLI (Venezia, Università, Venice, Italy) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 145-152. Copyright

The importance of internal damping for TSS-1 dynamics and stability is investigated. A model where longitudinal oscillation and subsatellite libration are coupled is analyzed to verify if such damping can counteract increasing amplitude of satellite rotations due to retrieval. An analytical formula is adopted to derive the dynamical equations to find the frequencies and modal ratios of the components of the motion for different values of the mechanical properties of the tether. Energetic considerations are taken into account in order to evaluate the amplitude increase due to the retrieval and the amplitude decrease due to damping. C.D.

**A89-43346\*** Stanford Univ., CA.

### TETHER DAMPING IN SPACE

J. DAVID POWELL (Stanford University, CA) and XIAOHUA HE IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 153-162. refs (Contract NCC2-389; NCA2-54)  
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This paper analyzes the dynamics of a long tether connecting two spacecraft in earth orbit, one of the spacecraft having dominant mass. In particular, it considers the material damping of the tether. The nominal position of the tether is stabilized by the gravity gradient such that it is aligned with the local vertical. The tether is modeled as a viscoelastic flexible continuum. Modal frequencies are derived in an analytical approximation form. Damping ratios are estimated according to the linear model calibrated by ground measurements. The results show that, with properly chosen tether material and braiding structure, longitudinal vibrations of the tethered system are well damped. *Author*

**A89-43347\*** Harvard-Smithsonian Center for Astrophysics, Cambridge, MA.

#### TETHER AS A DYNAMIC TRANSMISSION LINE

GORDON E. GULLAHORN (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA) and ROBERT G. HOHLFELD (Boston University, MA) *IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 163-168.*

(Contract NAS8-36810; NAS8-36606)

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The effect of longitudinal impulses on a satellite when a continuum tether from the Shuttle or Space Station is included is investigated. It is demonstrated that, taking the continuum nature of the tether into account, the sharp onset of a forcing impulse at the Shuttle end is perceived on board the satellite. The magnitude of the satellite response is diminished from that of the forcing impulse, and the response exhibits a broadened exponential tailoff. These are due primarily to the coupling between the tether and the satellite and its influence on an impinging impulsive wave, and not on the whole system as in the spring-mass model. The full impulse response function can be quite complex, showing repeated impulses as the tether wave bounces back and forth between the satellite and Shuttle, and having a different shape at each impingement on the satellite. *C.D.*

**A89-43348**

#### TETHER DYNAMICS AND VIBRATION ANALYSIS

R. L. ENGELSTAD and E. G. LOVELL (Wisconsin, University, Madison) *IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 169-173.*

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An assessment is made of the effects of tension gradients on the free vibrations of tethers. A perturbation procedure is developed in general terms. Specific cases considered include centrifugal loading and distributions from gravity gradients. Results indicate that such gradients can significantly alter natural frequencies, with changes nearly independent of wave number. Distortions in mode shapes also occur but are less severe. Node points and maximum amplitudes are shifted in the direction of decreasing tension. Equations of motion are presented for flow-induced vibrations in tethers used for fluid transfer, such as propellants and coolants. Response curves are obtained by numerical integration. It has been found that if the flow has a pulsating characteristic, large amplitude displacements are likely to develop over a wide range of system parameters. *Author*

**A89-43349\*** Stanford Univ., CA.

#### SHUTTLE ELECTRODYNAMIC TETHER SYSTEM

P. R. WILLIAMSON, P. M. BANKS (Stanford University, CA), and W. R. RAITT (Utah State University, Logan) *IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 177-185. refs*

(Contract NAS8-36812)

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The Shuttle Electrodynamic Tether System (SETS), an investigation of the interaction of a tethered satellite, a conducting tether, and the Orbiter with each other and with their environments

is discussed. The historical development of SETS and its objectives are reviewed. The SETS instrumentation is described, including the Tether Current and Voltage Monitor, Fast Pulse Electron Gun, Spherical Retarding Potential Analyzer and Langmuir Probe, Charge Current Probe, Digital Control and Interface Unit, and Dedicated Experiment Processor. The measurements to be made by SETS are examined, and its operations are briefly addressed. *C.D.*

**A89-43350**

#### PASSIVE CURRENT COLLECTION

W. B. THOMPSON (California, University, La Jolla) *IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 185-195. refs*

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Current collection by a large positively charged collector in LEO is shown to be possible with a modest voltage penalty, a collector of 500 sq m providing about 10 amps. The collection process is complex and unusual: ions are reflected, and the ambient plasma seriously disturbed over a volume greater than 10 to the 6th cu m, while plasma instabilities play an essential role. Physical processes are discussed, and the qualitative features of the current-voltage characteristics displayed. *Author*

**A89-43351**

#### LABORATORY INVESTIGATION OF THE ELECTRODYNAMIC INTERACTION OF A TETHERED SATELLITE IN AN IONOSPHERIC PLASMA/PRELIMINARY RESULTS

C. BONIFAZI, M. SMARGIASSI, G. VANNARONI (CNR, Istituto di Fisica dello Spazio Interplanetario, Frascati, Italy), and J. P. LEBERTON (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) *IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 196-205. Research supported by CNR. refs*

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The interaction of a highly polarized body in a mesosonic plasma has been investigated with particular emphasis on magnetic field effects. A laboratory program was started in order to get an insight into how the Tethered Satellite System (TSS) satellite may interact with its plasma environment. The topology and extension of the space charge region around actual body-sheath is investigated for both ion and electron current collection regimes with a magnetic field transverse to the plasma flow. *Author*

**A89-43353\*** TRW Space Technology Labs., Redondo Beach, CA.

#### PLASMA MOTOR GENERATOR TETHER SYSTEM FOR ORBIT REBOOST

NEAL D. HULKOWER and ROGER J. RUSCH (TRW, Inc., TRW Space and Technology Group, Redondo Beach, CA) *IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 211-216. Research supported by NASA. refs*

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This paper describes a comprehensive study of an electrodynamic tether used as a Plasma Motor Generator (PMG). The paper summarizes the work performed in the study and includes: (1) a detailed design of a 2 kW PMG tether system to be used for orbit reboost, (2) the selection of the Orbiting Maneuvering Vehicle (OMV) and the European Retrieval Carrier (EURECA) as the primary candidate spacecraft to host the experimental system, (3) analysis of the integration of the PMG tether system with these two spacecraft, (4) the simulation of the deployment of the tether, and (5) an engineering design and development plan leading to a flight demonstration of this PMG tether. *Author*

**A89-43357**

#### TSS CO/E EQUIPMENT - A HIGH PERVEANCE ELECTRON GENERATOR FOR THE ELECTRODYNAMIC MISSION

C. BONIFAZI (CNR, Istituto di Fisica dello Spazio Interplanetario,

Frascati, Italy). P. MUSI (Aeritalia S.p.A., Gruppo Sistemi Spaziali, Turin, Italy), G. CIRRI, and M. CAVALLINI (ISC S.p.A., Florence, Italy) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 230-240. refs

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The feasibility of an Electron Generator Assembly (EGA) for attaining the requirements of the TSS-1 mission is addressed. The EGA design approach, based on the cathode emission control of the electron generator by a loop which regulates the heating current of the cathode, is described. Test results on the efficiency divergency and pervence of a prototype electron generator are reported which show that the TSS-1 mission requirements are satisfied. C.D.

**A89-43363\*** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

#### INNOVATIVE USES OF TETHERS IN SPACE

RODICA IONASESCU and PAUL A. PENZO (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 305-313. refs

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Potential uses of tethers in the fields of science, transportation, electrodynamic, and space exploration are discussed. Special attention is given to the use of tethers for scientific and planetary application, with descriptions of the type of measurements to be performed in a given science field or a planetary body and the particular method of tether use. Experiments proposed regarding the use of tethers will address some of the pending issues regarding the use of tethers, such as the tether deployment and control laws, the recoil, electrodynamic effects, the strength and survivability of tethers in the lower atmosphere, the stability of a tethered platform, and the propulsion through momentum exchange. I.S.

**A89-43364\*** National Aeronautics and Space Administration, Washington, DC.

#### OUTER ATMOSPHERIC RESEARCH - ONE TETHER CAPABILITY

JOHN L. ANDERSON (NASA, Washington, DC) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 314-319. refs

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One specific tether application of far-reaching promise would be to conduct outer atmospheric research by using a tethered subsatellite deployed downward from an orbiting 'mother' craft such as the Shuttle Orbiter. This capability would gather scientific and engineering/technology information about the outer atmosphere, primarily from 150 km down to perhaps 90 km. This paper presents current determinations of specific user needs, tether capabilities, and technological and program requirements to fulfill this application of tethers in space. Author

**A89-43365\*** National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, AL.

#### A MANNED MARS ARTIFICIAL GRAVITY VEHICLE

DAVID N. SCHULTZ, CHARLES C. RUPP, GREGORY A. HAJOS, and JOHN M. BUTLER, JR. (NASA, Marshall Space Flight Center, Huntsville, AL) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 320-335.

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Data are presented on an artificial-gravity vehicle that is being designed for a manned Mars mission, using a 'split-mission' concept, in which an unmanned cargo vehicle is sent earlier and stored in a Mars orbit for a rendezvous with a manned vehicle about 1.5 years later. Special attention is given to the vehicle trajectory and configuration, the tether design, and the vehicle

weight and launch requirements. It is shown that an artificial-G vehicle for a manned Mars mission is feasible technically and programmatically. Using an artificial-G vehicle instead of a zero-G vehicle for the piloted portion of a split mission provides physiological and human-factor-related benefits, does not eliminate requirements for zero-G countermeasures research (since zero-G is an abort mode), and could possibly reduce some life science activities. Diagrams are included. I.S.

#### **A89-43366** SPACE ELEVATORS AND SPACE TETHERS - ROTATING STRUCTURES IN SPACE

JEROME PEARSON (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 339-348. refs

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Space tethers have a long and interesting history, beginning with the 'space elevator', a device for connecting a geostationary satellite to the ground. They belong to a class of rotating structures in space that includes 'orbital rings' and 'rotary rockets'. This paper gives an account of rotating structures in space, from the earliest dreams through the technical solutions, including several re-inventions and extensions along the way. A perspective is given of such structures, including their range of applications and a discussion of their place in the future of space development. Author

#### **A89-43367** TETHER APPLICATIONS IN THE EUROPEAN SCENARIO

C. A. MARKLAND (ESA, Paris, France) and F. GIANI (Aeritalia S.p.A., Naples, Italy) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 347-352. refs

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This paper discusses potential applications of tethers as determined from an investigation into the interests and the opportunities in the European space scenario. Thus, it covers the scientific interest from the various space science domains, Earth Observation and microgravity, and Columbus and Hermes operations. Also, it discusses the opportunities arising from the Columbus, Eureka, Ariane, and Hermes scenarios. Brief feasibility studies of two missions are presented together with their technology requirements and constraints. Author

#### **A89-43368\*** Consiglio Nazionale delle Ricerche, Rome (Italy). REPORT ON THE ACTIVITIES OF THE PSN/NASA TASK GROUP

ALBERTO LORIA (CNR, Piano Spaziale Nazionale, Rome, Italy) and JAMES K. HARRISON (NASA, Marshall Space Flight Center, Huntsville AL) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 353-364.

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Since July '86 the PSN/NASA Task Group for Tether Flight Demonstrations has been working to find applications of tethers in space, the development of which might be of mutual interest to the two agencies. Seven projects have so far been identified and some more will probably be added. A technical evaluation and a managerial plan have been outlined for each. Author

#### **A89-43369** THE TETHERED SPACE ELEVATOR SYSTEM

FRANCO BEVILACQUA and PIETRO MERLINA (Aeritalia S.p.A., Gruppo Sistemi Spaziali, Turin, Italy) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 365-373. refs

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The configuration and the key features of the Tethered Space



Elevator (TSE) system, presently being developed for the Space Station, are described, and the characteristics of the TSE subsystems are analyzed. Special attention is given to the drive mechanisms and the thermal control system, as well as to the power, communications, and data handling. Possible applications of the TSE are identified. Concept diagrams are included. I.S.

**A89-43370**

**ENVIRONMENTAL FACTORS AFFECTING ATMOSPHERIC RESEARCH WITH TETHERED SATELLITES**

JACK W. SLOWEY (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 374-378. refs

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A tethered probe that could be deployed downward from an orbiting spacecraft will provide a unique resource for obtaining data from the height range 90-130 km. Problems that can be expected in both the functionality of instruments and the interpretation of results as a result of environmental factors resulting from the velocity of the probe and the greater density of the atmosphere below 125 km are discussed. Some of the factors of special concern are gas-gas interactions, shock wave formation, excessive heating of the instrument packages, ionization in the shock front and on surfaces, and surface chemical reactions. I.S.

**A89-43371\*** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

**THE USE OF TETHERS FOR AN ARTIFICIAL GRAVITY FACILITY**

L. G. LEMKE, A. F. MASCY, and B. L. SWENSON (NASA, Ames Research Center, Moffett Field, CA) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 379-387. refs

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The principles of operation and the design of the Artificial Gravity Research Facility (AGRF), which is a centrifuge to be constructed and operated for research and development purposes in a low-earth orbit, are examined, with particular attention given to the use of tethers for this facility. The differences and similarities between the AGRF and the previous artificial-gravity concepts are discussed in the framework of modern understanding of the effects of partial gravity and rotating environments on the human organism. The impact of tension-stiffened tethers on the system mass of the AGRF is examined, together with their effect on space operations and safety. I.S.

**A89-43372**

**THE DYNAMICS OF TETHERS IN ARTIFICIAL GRAVITY APPLICATIONS**

JOHN R. GLAISE (Control Dynamics Co., Huntsville, AL) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 388-393.

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Artificial gravity can be generated in space by centrifugal forces. Tethers can be used to bind together systems of masses revolving about a common center. To assess the potential problems associated with such configurations it is desirable to investigate candidate concepts. This paper discusses deployment, spinup, despin, and retrieval. The dynamic behavior of a configuration consisting of two bodies connected by a flexible tether of nonnegligible mass is investigated. Results from simulations of the spinup operation are presented. Tether dynamic behavior will have a significant impact on the feasibility of these concepts. The requirement for suppression of tether oscillations imposes limitations on speed of deployment and retrieval. Deployment and retrieval scenarios are proposed and considered. Preliminary results do not indicate a need for special control laws to damp lateral oscillations. Author

**A89-43373**

**LOWER THERMOSPHERE STUDIES FROM TETHER**

J. H. HOFFMAN and R. R. HODGES, JR. (Texas, University, Richardson) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 394-396. refs

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Experiments planned for a low-altitude tethered satellite mission, which is being planned for studies on the composition, concentrations, and wave structure of the neutral and ionized components of the lower thermosphere (i.e., from 100 to 130 km heights), are discussed. One goal of these studies is to measure total hydrogen content (H, H<sub>2</sub>, H<sub>2</sub>O, and CH<sub>4</sub>) and use these data to improve the estimate of the global escape flux of hydrogen. The instrument that is being designed for this purpose is a neutral gas/ion magnetic sector mass spectrometer that has a mass range that extends from 2 through 65 amu in its three channels, and has a retarding voltage (RV) grid incorporated into the ion beam path within the instrument. The RV grid will be used to separate ambient gas molecules from contaminant species, and in the analysis of the distribution velocity of the ambient gas molecules along the satellite flight path. I.S.

**A89-43374**

**TETHERED 'SPACE MAIL'**

R. MONTI and R. FORTEZZA (Univ. Napoli, Napoli, Italy) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 397-409. refs

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A mail system for transporting samples from scientific experiments on the Space Station to the ground is proposed. The system uses a tether to deliver small capsule in the reentry trajectory to avoid the need for a propulsive system that might not be compatible with the manned station. Numerical parametric computations are carried out to demonstrate the feasibility of using an entirely passive low ballistic parameter reentry capsule. In addition, impact point computations are presented for possible ground or sea retrievable systems. R.B.

**A89-43375**

**A PRELIMINARY STUDY OF THE DYNAMICAL STABILITY OF A SPINNING TETHER**

W. B. THOMPSON and S. GIERMAN (California, University, La Jolla) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 413-415. Research supported by the University of California.

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It is shown that in its simplest representation, a tether rotating in the orbital plane can be unstable. For particular values of the rotation frequency, a small out-of-plane disturbance grows to a large value. Author

**A89-43376**

**TETHERED DIAGNOSTIC PACKAGE FOR USE FROM THE SPACE STATION**

JAMES D. SULLIVAN, RICHARD S. POST, JAMES H. WILBY (MIT, Cambridge, MA), and ENRICO C. LORENZINI (Smithsonian Astrophysical Observatory, Cambridge, MA) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 416-423. refs

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The interaction in the upper ionosphere between the ambient medium and Space Station or other orbiting vehicles in the 1990s will require measurements from essentially nonintrusive instrumentation and the ability to repeat those measurements at will in an extended region. A spin-cast diagnostic package (SCDP) can complement free flyers and attached instrumentation in the region from 10 m to 1 km. The basic concept for the SCDP is to cast off, probably electro-magnetically, a fiber-optic line in some

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chosen direction a small battery-powered instrumentation package and then reel it back in while making measurements. The SCOP instrumentation package might include pressure monitors, and various plasma probes, magnetometers and plasma-wave and optical sensors. The dynamics of deployment and retrieval maneuvers of the SCOP is analyzed. Strategies for casting the package in any given direction from the Space Station are devised. Fast, impulsive retrieval maneuvers with negligible tension in the tether are also investigated. *Author*

**ABN-43378\*** Harvard-Smithsonian Center for Astrophysics, Cambridge, MA.

### STUDY OF AN ORBITING TETHERED DUMBBELL SYSTEM HAVING POSITIVE ORBITAL ENERGY

DAVID A. ARNOLD (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 433-443.

(Contract NAS8-33691)

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For very long tethered systems the sum of the kinetic and potential energy can be positive. The system remains in a circular orbit as long as the masses remain vertically aligned. The system is unstable without constant control of the alignment. If the upper mass rotates forward in the direction of the orbital motion, the system escapes out of orbit. If the upper mass rotates backward, the system falls out of orbit and the lower mass impacts the body around which the system is orbiting. *Author*

**ABN-43379**

### DYNAMICS AND CONTROL OF THE SPACE STATION BASED TETHERED PAYLOAD

P. K. LAKSHMANAN, V. J. MOOI, and A. K. MISRA (British Columbia, University, Vancouver, Canada) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 444-452. refs

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A mathematical model is proposed here for studying the dynamics of the Tethered Satellite System (TSS) that consists of a plate-type Space Station from which a tether supported sub-satellite is deployed or retrieved. The rigid body dynamics of the tether, sub-satellite and Space Station are analyzed accounting for the mass of the tether as well as a three-dimensional offset of its point of attachment. Controllability of the linearized equations is established numerically and a comparative study of three different control strategies conducted. The strategies employ thrusters, tension in the tether line or motion of the offset of the attachment to achieve control of the system subjected to a relatively large initial disturbance. Results suggest that, in the station-keeping mode, the tension control strategy damps a given disturbance in the shortest time, however, at an expense of the energy. On the other hand, the offset control proves to be the most efficient in terms of energy consumption, but now the response to disturbance persists over a long duration. *Author*

**ABN-43380**

### ORDER OF MAGNITUDE EVALUATION OF THE LIFETIME OF A FREE TETHER IN ORBIT

S. BERGAMASCHI and M. MORANA (Padua, Università, Italy) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 453-460. Research sponsored by CNR. refs

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The purpose of the present work is to give an order of magnitude estimate of the orbital lifetime of a free (i.e. with no masses at its ends) tether in space. Three different simple models are used. Their results are discussed and compared. It is concluded that the decay times are fairly short, being at most a few days from the Space Station orbit. *Author*

**ABN-43381**

### THERMAL EFFECTS ON TETHER DYNAMICS

SILVANO SGUBINI (Roma I, Università, Roma, Italy) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 461-467. refs

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The coupling effects between the longitudinal motion of a tether, caused by variation on thermal input, and the transversal motion are analyzed by means of simplified models. The conditions in order to decouple the thermal and displacement field are examined and, when verified, the dynamic response is obtained in a close form for a first-order model and, by numerical integration, for a second-order model. *Author*

**ABN-43382**

### EFFECT OF ATTITUDE DYNAMICS ON TETHER PROPULSION

A. K. MISRA (McGill University, Montreal, Canada), V. J. MOOI (British Columbia, University, Vancouver, Canada), and Z. E. AMER IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 468-476. refs

(Contract NSERC-A-2181; NSERC-A-0967)

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One of the possible uses of tethered systems is to raise payloads to higher orbits through momentum transfer. This paper examines how the orbit attained by the payload is affected by the attitude dynamics of the tethered system before release. Three-dimensional librational motions of the tethered system (pitch and roll) are considered, but the vibrations of the tether are ignored. The larger the amplitude of the pitch oscillations, the larger is the apogee height of the orbit attained by the payload released upward. However, roll oscillations may lead to apogee heights that are lower than the case when roll is absent. The instants (within the pitch and roll angles) when the payload should be released to maximize the altitude reached are also indicated. *Author*

**ABN-43383\*** Martin Marietta Corp., Denver, CO.

### TETHERED SYSTEM/SPACE PLATFORM INTEGRATION - TSS LESSONS LEARNED

L. K. RUDOLPH (Martin Marietta Corp., Denver, CO) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 479-488. refs

(Contract NAS8-36000)

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Tethered spacecraft systems must be integrated with their user platforms in a way that allows both to carry out their design functions efficiently and safely. This paper describes the lessons learned about tethered system integration with a space platform from the NASA/PSN Tethered Satellite System. Items discussed include platform attitude control, induced voltage and current control, satellite tracking and tether length measurement, satellite communications and system operations sensitivities. A number of engineering issues yet to be resolved are noted. Tethered systems are complex and require careful design to ensure successful operation. *Author*

**ABN-43384**

### TETHER APPLICATIONS SCENARIOS FOR SPACE STATION/PLATFORMS SYSTEMS

JAMES D. WALKER (Martin Marietta Corp., Denver, CO) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 489-498. refs

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A set of scenarios including tether applications for a Space Station system for the next 20 yrs is described. Permanent orbiting platforms near the core (manned base) space station will be included. The tether applications scenarios include incorporation

of a variable gravity laboratory, a full-sized tether deployment system, a space-based OTV, and permanent tethered experiments. K.K.

**A89-43385\*** National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, AL.

#### CONSIDERATION OF SPACE STATION REQUIREMENTS FOR TETHERS

M. R. CARRUTH, JR. (NASA, Marshall Space Flight Center, Huntsville, AL) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 499-504. refs

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Space Station requirements with regard to tethers are discussed with attention given to environmental requirements and Space Station plasma considerations. Conducting tethers can be used for electrodynamic experiments, power generation, and propulsion. It is noted that the use of nonconducting tethers with plasma contactors will produce dynamic effects which may alter the relationship between the Space Station and the ambient plasma. K.K.

**A89-43386**

#### SPACE STATION GRAVITY GRADIENT STABILIZATION BY TETHERS

F. BEVILACQUA, S. CIARDO (Aeritalia S.p.A., Gruppo Sistemi Spaziali, Turin, Italy), and A. LORIA (CNR, Piano Spaziale Nazionale, Rome, Italy) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 505-512.

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The possible application of tethered masses to decrease the total amount of energy and fuel required by the Space Station is examined. Candidate tether system configurations are studied using simple analytical models. Preliminary analyses confirm that the method may be successfully applied in attitude control. R.B.

**A89-43387\*** Harvard-Smithsonian Center for Astrophysics, Cambridge, MA.

#### ACCELERATION LEVELS ON BOARD THE SPACE STATION AND A TETHERED ELEVATOR FOR MICRO AND VARIABLE-GRAVITY APPLICATIONS

E. C. LORENZINI, M. COSMO (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA), S. VETRELLA, and A. MOCIA (Napoli, Università, Naples, Italy) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 513-522. Research supported by CNR. refs (Contract NAS8-36606)

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This paper investigates the dynamics and acceleration levels of a new tethered system for micro and variable-gravity applications. The system consists of two platforms tethered on opposite sides to the Space Station. A fourth platform, the elevator, is placed in between the Space Station and the upper platform. Variable-g levels on board the elevator are obtained by moving this facility along the upper tether, while micro-g experiments are carried out on board the Space Station. By controlling the length of the lower tether the position of the system CM can be maintained on board the Space Station despite variations of the station's distribution of mass. The paper illustrates the mathematical model, the environmental perturbations and the control techniques which have been adopted for the simulation and control of the system dynamics. Two sets of results from two different simulation runs are shown. The first set shows the system dynamics and the acceleration spectra on board the Space Station and the elevator during station-keeping. The second set of results demonstrates the capability of the elevator to attain a preselected g-level. Author

**A89-43388**

#### DOUBLE TETHER SYSTEM IMPROVING AUTOMATIC DOCKING MANOEUVRES

A. ERCOLI FINZI and B. MIGNEMI (Milano, Politecnico, Milan, Italy) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 523-531. refs

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The dynamics of a double tether system is analyzed in an attempt to improve docking maneuvers. It is noted that different conditions arise when the docking harbor is located on the end of the secondary tether. The motion around the vertical stable equilibrium configuration is determined and simulations are performed to assess the influence of different parameter values on satellite dynamic behavior and on tether tension. K.K.

**A89-43389\*** National Aeronautics and Space Administration, Ames Research Center, Moffett Field, CA.

#### A TETHERED ASTROMETRIC TELESCOPE FACILITY

L. G. LEMKE and M. A. SMITH (NASA, Ames Research Center, Moffett Field, CA) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 532-544. refs

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A comparison is made between a tethered platform and a kinematically attached payload. Tethered platforms are capable of achieving a high level of passive vibration attenuation while reducing exposure to induced contamination to near-background levels. The Astrometric Telescope Facility, a payload being considered for operation from the Space Station, is described in detail. K.K.

**A89-43390**

#### THE USE OF TETHERS TO CONSTRUCT AND DEPLOY SOLAR SAILS FROM THE SPACE STATION

J. M. GARVEY and R. W. ADKISSON (McDonnell Douglas Astronautics Co., Huntington Beach, CA) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 545-550. refs

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This paper addresses the assembly and deployment of advanced solar sails from the international Space Station. Tethers perform several important tasks in this process. During sail assembly, a 50- to 100-km tether attaches a sail and its sail construction platform (SCP) to the Station. Concurrently, shorter tethers (not longer than 1 km) on the SCP transfer loads from the sail to the SCP, thereby reducing structural deformation of the sail. Later, during deployment of the finished product, the primary tether is used to boost the sail into an acceptable transfer orbit. The resulting sails will have either cost or performance advantages, or both, over chemical, nuclear, and electric rockets on a variety of interplanetary missions. Author

**A89-43391**

#### TRANSPORTATION OF PAYLOADS FROM SUB-ORBITAL TRAJECTORY TO THE SPACE STATION USING LONG TETHERS

EDMONDO T. TICI (Aeritalia S.p.A., Gruppo Sistemi Spaziali, Turin, Italy) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 552-558.

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A first-approximation analysis calculation is presented which supports the suggested feasibility of the use of a transportation system in which a docking/recovery mechanism is attached to the NASA Space Station by means of a tether. This system, which can accomplish the docking and recovery of a vehicle that has reached a predetermined trajectory, entails no advanced technology. The most promising solution is that initially conceived



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as the baseline, involving a missile whose booster and second stage both employ liquid propellants. The transport aircraft deploying the missile may be of B747 or Airbus airliner type.

O.C.

**A89-43392\*** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.

### SPACE STATION TETHERED WASTE DISPOSAL

CHARLES C. RUPP (NASA, Marshall Space Flight Center, Huntsville, AL) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 559-563.

Copyright

The Shuttle Transportation System (STS) launches more payload to the Space Station than can be returned creating an accumulation of waste. Several methods of deorbiting the waste are compared including an OMV, solid rocket motors, and a tether system. The use of tethers is shown to offer the unique potential of having a net savings in STS launch requirement. Tether technology is being developed which can satisfy the deorbit requirements but additional effort is required in waste processing, packaging, and container design. The first step in developing this capability is already underway in the Small Expendable Deployer System program. A developmental flight test of a tether initiated recovery system is seen as the second step in the evolution of this capability.

Author

**A89-43393**

### TETHER CAPABILITY TO RETURN SPACE STATION MATERIAL

M. BURGIO and C. CHIARELLI (Aeritalia S.p.A., Gruppo Sistemi Spaziali, Turin, Italy) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 564-569. refs

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The possibility of using a tether deployed toward earth to give the Space Station an independent capability to recover or burn-up materials is examined. The salient features of the following three types of tether reentry systems are described: (1) a disposable capsule deployed from the Space Station by a disposable tether that will be cut, (2) a reusable tether system, and (3) an elevator-based tether system permanently deployed. The common features of the three systems are that they give rise to a small reentry angle, the capsule's mass distribution does not affect the deorbit maneuver; and the reentry procedure results in Space Station reboosting. The specific requirements of each system and their benefits and drawbacks are discussed.

I.S.

**A89-43395**

### A THRUSTED SLING IN SPACE - A TETHER-ASSIST MANEUVER FOR ORBIT TRANSFER

MAURO PECCHIOLI (Telespazio S.p.A., Rome, Italy) and FILIPPO GRAZIANI (Roma I, Università, Rome, Italy) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 576-580.

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A new strategy is described for the tether-assisted orbit transfer of a satellite payload, which avoids the use of exaggeratedly long tethers by using a thrusting phase of the payload before its release. The paper describes a maneuver which could perform, at the same time, the injection of the payload from the Orbiter into a higher orbit and the braking of the Orbiter for starting its reentry into the atmosphere. The analysis of the maneuver shows that it is viable, but that its performance requires very sophisticated future materials. Problems remaining to be solved include the complex attitude maneuvers required for both systems, the low reliability of such a maneuver (the major risk of which is an unsuccessful deorbit of the Orbiter), and high-level accelerations experienced by both spacecraft systems.

I.S.

**A89-43396\*** Anco Engineers, Inc., Culver City, CA.

### AN OVERVIEW OF A TETHER DEPLOYMENT MONITORING SYSTEM

P. IBANEZ and A. LEVI (ANCO Engineers, Inc., Culver City, CA) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 587-596. refs (Contract NAS8-36368)

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A study was conducted to investigate the feasibility of monitoring the position of a tether during tether deployment. Several major configurations were investigated, including considerations of passive or active optical detection, radar, lidar, and active instrumentation packages. Cost, weight, the impact on tether operational dynamics, and the orbiter integration considerations were studied for each of these methods. Results indicated that implementation of such a monitoring system can be accomplished with little or no impact on tether deployment operations. Design diagrams are presented for two launchers and a tether attitude/tension detector.

I.S.

**A89-43397\*** Auburn Univ., AL.

### SIMULATION AND MEASUREMENT OF DISTURBANCE PROPAGATION IN A SINGLE TETHER SYSTEM

MICHAEL GREENE, J. THERON CARTER (Auburn University, AL), and CHARLES C. RUPP (NASA, Marshall Space Flight Center, Huntsville, AL) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 597-604. refs

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One of the missions of the Getaway Tether Experiment (GATE) is to investigate disturbance propagation and control in a tethered system. In order to understand the nature of the propagation, simulation of the tether response is vital. A single finite duration pulse is the source of the disturbance. A bead model is used to predict the motion of the tether and the end masses (modeled as point masses). System response is checked for different magnitudes of force and for different points of impact on the tether. Along with simulation, hardware development is needed, especially in the area of tension measurement. At this time, hardware is being developed to measure the tension in the tether, so that the tethered system can be controlled via tension feedback. The hardware will then be tested in conjunction with the Dynamics and Control Mission of the GATE project.

Author

**A89-43398\*** Tri-State Univ., Angola, IN.

### OPTIMIZATION OF MOTION CONTROL LAWS FOR TETHER CRAWLER OR ELEVATOR SYSTEMS

FRANK R. SWENSON (Tri-State University, Angola, IN) and GEORG VON TIESENHAUSEN (NASA, Marshall Space Flight Center, Huntsville, AL) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 605-608. refs

(Contract NGT-01-002-099)

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Based on the proposal of a motion control law by Lorenzini (1987), a method is developed for optimizing motion control laws for tether crawler or elevator systems in terms of the performance measures of travel time, the smoothness of acceleration and deceleration, and the maximum values of velocity and acceleration. The Lorenzini motion control law, based on powers of the hyperbolic tangent function, is modified by the addition of a constant-velocity section, and this modified function is then optimized by parameter selections to minimize the peak acceleration value for a selected travel time or to minimize travel time for the selected peak values of velocity and acceleration. It is shown that the addition of a constant-velocity segment permits further optimization of the motion control law performance.

I.S.

**A89-43400**

### TECHNOLOGIES APPLICABLE TO SPACE TETHERS

WILLIAM A. BARACAT (General Research Corp., McLean, VA) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 615-620. Previously announced in STAR as N88-25471. refs  
Copyright

An investigation is presented of technologies which have been accumulated over the years, both on earth and in space, dealing with tethers, ropes and cables. Many of these technologies can be applied, with modification, to both ongoing and future space tether research and demonstration missions. The major areas of tether research and technology developments presented include multimegawatt power transmission, materials and structures, dynamics and control, environmental interactions, and in-space operations. These major topical areas are presented within the context of their associated research program or study. Author

**A89-43401\*** Martin Marietta Corp., Denver, CO.

**ACCEPTANCE AND QUALIFICATION TEST RESULTS OF THE 20 KM ELECTROMECHANICAL TETHER FOR TSS-1**

L. S. MARSHALL (Martin Marietta Corp., Denver, CO) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 621-625. (Contract NAS8-36000)  
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Acceptance and qualification tests have been performed on the TSS-1 flight tether and its associated qualification tether. Acceptance testing during production included periodic measurement of conductor resistance, off-line breakstrength tests on strength member samples, continuous measurement of the insulation layer voltage withstand capability, and a continuous mechanical proof-loading procedure during the tether jacketing operation. The qualification test sequence consisted of thermal vacuum, voltage withstand and breakstrength tests on samples taken from the production runs for both the qualification and flight tethers. This paper will analyze the acceptance and qualification test data, respectively. Results indicate that the completed flight tether exceeds the design requirements for the TSS-1 mission. Author

**A89-43402**

**TSS-2 AND FUTURE TSS MISSION TECHNOLOGY**

ANDREA LORENZONI (CNR, Piano Spaziale Nazionale, Rome, Italy), ETTORE ALLAIS (Aeritalia S.p.A., Naples, Italy), and TOM MEGNA (Martin Marietta Corp., Denver, CO) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 626-636.  
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Research in preparation for the Tethered Satellite System 2 (TSS-2) mission is discussed. The TSS-2 deployer and its subsystems are described, noting modifications made to the design of the TSS-1 deployer, including changes to the tether and tether attachment device, the slip ring assembly, level wind gear, brake assembly, umbilical actuator assembly, NASA standard initiators, motor control assembly, and software. The TSS-2 mission requirements are listed and the atmospheric mission profile is outlined. The design of the atmospheric satellite is examined, including the performance of the attitude and thermal control systems. The communication and tracking system options for future TSS missions are considered. R.B.

**A89-43403\*** Martin Marietta Corp., Denver, CO.

**HYPERVELOCITY IMPACT TESTING OF TETHERS**

WILLIAM R. WOODIS (NASA; Martin Marietta Corp., Denver, CO) and FRANCIS I. TALLENTIRE IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 637-642. refs  
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An experimental test program has been conducted to ascertain the strength losses to which representative space tether materials

may be prone upon impact by hypervelocity particles of known size, density, and velocity, when the tether is under tensile loading typical of flight design loads. Twelve hypervelocity impacts were followed by tensile tests to failure to determine residual strength; relationships are established between particle velocity and strength loss due to impact damage, as well as between tether strength loss and the relationship between particle and tether diameters. Tentative design criteria are formulated in terms of a design factor allowing for strength degradation by impact. O.C.

**A89-43404\*** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

**THE TETHER INSPECTION AND REPAIR EXPERIMENT (TIRE)**

GEORGE M. WOOD (NASA, Langley Research Center, Hampton, VA), ALBERTO LORIA (CNR, Piano Spaziale Nazionale, Rome, Italy), and JAMES K. HARRISON (NASA, Marshall Space Flight Center, Huntsville, AL) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 643-646.  
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The successful development and deployment of reusable tethers for space applications will require methods for detecting, locating, and repairing damage to the tether. This requirement becomes especially important whenever the safety of the STS or the Space Station may be diminished or when critical supplies or systems would be lost in the event of a tether failure. A joint NASA/PSN study endeavor has recently been initiated to evaluate and address the problems to be solved for such an undertaking. The objectives of the Tether Inspection and Repair Experiment (TIRE) are to develop instrumentation and repair technology for specific classes of tethers defined as standards, and to demonstrate the technologies in ground-based and in-flight testing on the STS. Author

**A89-43405**

**A SENSOR FOR THE MEASUREMENT OF THE ATTITUDE OF THE SUBSATELLITE RELATIVE TO THE TETHER IN THE TSS SYSTEM**

ALESSANDRO CAPORALI and GIULIO CALORE (Padova, Università, Padua, Italy) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 647-650. Research supported by CNR.  
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A sensor has been developed for the Tethered Satellite System to determine the librational motion of the subsatellite relative to the tether or the curvature of the tether at the subsatellite. The design and performance of the sensor are discussed. The attitude sensor is based on the magnetic induction sensed by a Hall gage pick-up. It is suggested that the resolution, linearity, and long-term stability of the sensor make it possible to measure oscillations up to two degree of amplitude with 5 percent uncertainty. R.B.

**A89-43406**

**AN ALGORITHM FOR THE DETECTION ON THE EARTH SURFACE OF POSSIBLE E.M. EMISSIONS IN THE ELF/ULF BAND BY THE ORBITING ELECTRODYNAMIC TETHER OF THE TSS SYSTEM**

P. NICOLAS (NATO, Saclant Anti-Submarine Warfare Research Centre, La Spezia, Italy) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Società Italiana di Fisica, 1988, p. 653-657. refs  
(Contract CNR-PSN-87,022)  
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The Tether Satellite System (TSS) of the NASA PSN project, which consists of a 20 km long tether and its associated system components is expected to generate electromagnetic radiation in the ULF/ELF/VLF bands via the interaction of the tether with the earth's magnetic field and ionosphere. The work presented here describes one of the processing methods to be used with a ground-based system in order to receive and verify the existence

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of such radiations. The principle of the method, based on an estimation-detection scheme, is detailed in this paper. Results obtained using simulated data are shown and a comparison with conventional detection methods is achieved. Author

**A89-43407**

### **TETHER MANIPULATOR**

O. BSCHORR (Messerschmitt-Boelkow-Blohm GmbH, Munich, Federal Republic of Germany) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 658-660. refs  
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The object of this paper is a 'tether crane' for manipulation and docking purposes not only close to the Space Station but also in kilometer distances. The tether will be used as a wave guide for bending waves and string waves. As a wave transports not only energy but also forces and torques, it is possible to move the wave guiding tether in all translatory and rotatory directions like a rigid bar. For this purpose, the following three wave effects will be used: the radiation force, circular polarized waves, and asymmetrical wave shapes. Because of the radiation force, the tether will be stretched. Author

**A89-43638**

### **MARS ON \$800,000 A DAY**

KELLY PARKS and BEVIN MCKINNEY (American Rocket Co., Camarillo, CA) Space Power (ISSN 0951-5089), vol. 7, no. 3-4, 1988, p. 327-344. refs  
Copyright

Manned Mars missions are expected to cost \$100 billion or more. It will be shown that, with the proper exploration strategy, not only can this cost be brought down by nearly two orders of magnitude, such that the mission could be financed by private investors, but also that a substantial profit could be made. Author

**A89-43702**

### **SPACE - A NEW COMMUNITY OF OPPORTUNITY; PROCEEDINGS OF THE THIRTY-FOURTH ANNUAL AAS INTERNATIONAL CONFERENCE, HOUSTON, TX, NOV. 3-5, 1987**

WILLIAM G. STRAIGHT, ED. (Lockheed Missiles and Space Co., Inc., Houston, TX) and HENRY N. BOWES, ED. (Lockheed Engineering and Management Services Co., Inc., Houston, TX) Conference sponsored by AAS, San Diego, CA, Univelt, Inc., 1989, 470 p. For individual items see A89-43703 to A89-43721.  
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Papers on recent advances in astronautical sciences are presented, covering topics such as governing and policy issues, international space applications, ELV research, astrodynamics and planetary missions, and rocket propulsion for the Space Shuttle and the National Aerospace Plane. Other topics include astronomy, astrophysics, solar system exploration, physiological effects of space flight, bioregenerative life support, medical care in space, tracking and data systems, VLBI, electrophoresis experiment command and data handling, Space Station communications, and telerobotics. Additional subjects include structures and composite materials, automation and robotics for the Space Station, EVA construction, the Space Station and large structures, and automation and robotics for the moon, Mars, and interplanetary missions. R.B.

**A89-43704**

### **INDUSTRIAL APPLICATIONS OF THE MICRO-GRAVITY ENVIRONMENT**

L. J. EVANS, JR. (Center for Space and Advanced Technology, Arlington, VA) IN: Space - A new community of opportunity; Proceedings of the Thirty-fourth Annual AAS International Conference, Houston, TX, Nov. 3-5, 1987. San Diego, CA, Univelt, Inc., 1989, p. 105-108.  
(AAS PAPER 87-619) Copyright

In the previous session this morning, the panel addressed how

government and industry must work together to re-establish access to space. Restoring U.S. access to space is an essential step in order to enable a broad spectrum of business opportunities to develop in space. In addition to restoring U.S. access to space, two other fundamentals are needed. A strong and growing, independent U.S. enterprise of risk-building investments in space requires that the private sector also have confidence in (1) our ability to live and work in space, and (2) the ability of government to perform as a reliable partner. Author

**A89-44418**

### **BUILDING THE HUBBLE SPACE TELESCOPE**

C. ROBERT O'DELL (Rice University, Houston, TX) Sky and Telescope (ISSN 0037-6604), vol. 78, July 1989, p. 31-36.  
Copyright

The development of the design for the Hubble Space Telescope (HST) is discussed. The HST optical system is described and illustrated. The financial and policy issues related to the development of the HST are considered. The actual construction of the HST optical telescope is examined. Also, consideration is given to the plans for the HST launch. R.B.

**A89-44489**

### **LIFE SCIENCES AND SPACE RESEARCH XXIII(1): EXOBIOLGY SCIENCE AND PRIMITIVE SOLAR SYSTEM BODIES; PROCEEDINGS OF WORKSHOP XXII OF THE 27TH COSPAR PLENARY MEETING, ESPOO, FINLAND, JULY 18-29, 1988**

J. ORO, ED. (Houston, University, Texas) Meeting Sponsored by COSPAR. Advances in Space Research (ISSN 0273-1177), vol. 9, no. 2, 1989, 127 p. For individual items see A89-44490 to A89-44505.  
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Papers on exobiology and primitive solar system bodies are presented, covering topics such as observational astrochemistry, interstellar dust as a source of organic molecules in Comet Halley, the origin of the P/Halley dust component, polymeric organic molecules in Comet Halley, organic ions in the atmosphere of Comet Halley, and organic solids produced from C/H/O/N ices by charged particles. Other topics include cometary organics and the 3.4-micron spectral feature, organic compounds in carbonaceous chondrites, macromolecular carbon compounds on the dark surfaces of asteroids and comets, results concerning Titan, a possible ocean on Europa, comets as a source of preformed material for prebiotic evolution, and the Gas-Grain Simulation Facility on the Space Station. In addition, consideration is given to the origin of precursors of organic molecules during evaporation of meteorites and rocks, the origin of organics on clays, and chemical evolution of primitive solar system bodies. R.B.

**A89-44502\*** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

### **MICROGRAVITY PARTICLE RESEARCH ON THE SPACE STATION - THE GAS-GRAIN SIMULATION FACILITY**

G. FOGLEMAN, J. L. HUNTINGTON, G. C. CARLE (NASA, Ames Research Center, Moffett Field, CA), and J. A. NUTH (NASA, Goddard Space Flight Center, Greenbelt, MD) Advances in Space Research (ISSN 0273-1177), vol. 9, no. 2, 1989, p. 91-94. refs  
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In the gravitational field on earth, the large settling rate of micron-sized particles and the effects of gravity-induced convection prohibit many interesting studies of phenomena such as coagulation, collisions, and mutual interactions of droplets, dust grains and other particles. Examples of exobiology experiments involving these phenomena are the simulation of organic aerosol formation in Titan's atmosphere, studies of the role of comets in prebiotic chemical evolution, and simulations of carbon grain interactions in various astrophysical environments. The Gas-Grain Simulation Facility (GGSF) is a proposed earth-orbital laboratory that will allow present ground-based experimental programs which study processes involving small particles and weak interactions to be extended to a new domain. Physics issues that scientists wishing to propose GGSF experiments must consider are reviewed in this



paper. Specifically, coagulation, motion in gases and vacua, and wall deposition of particles in a microgravity environment are discussed. Author

**A89-45783\*** National Aeronautics and Space Administration, Washington, DC.

# **AN OVERVIEW OF THE EASE/ACCESS SPACE CONSTRUCTION DEMONSTRATION**

GEORGE M. LEVIN (NASA, Washington, DC), JERRY L. ROSS, and SHERWOOD C. SPRING (NASA, Johnson Space Center, Houston, TX) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 712-721.

Copyright

Consideration is given to the development of the Experimental Assembly of Structures in EVA/Assembly Concept for Construction of Erectable Space Structures (EASE/ACCESS) space construction demonstration, which was performed during Space Shuttle mission 61-B. The mission equipment is described and illustrated and the EASE/ACCESS mission management structure is outlined. Simulations of the assembly and disassembly in the NASA neutral buoyancy simulators were used to test the mission plans. In addition, EVA training and crew performance for the mission are discussed. R.B.

**A89-45784\*** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

# **SPACE TRUSS CONSTRUCTION STUDIES**

WALTER L. HEARD, HAROLD G. BUSH, and JUDITH J. WATSON (NASA, Langley Research Center, Hampton, VA) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 722-733. refs

Copyright

The ACCESS Shuttle Flight Experiment, designed to evaluate EVA for on-orbit assembly of erectable truss structure, is reviewed and principal results are summarized. In addition, two on-going ground test programs that address EVA assembly of full scale Space Station truss structure using a mobile transporter are described. A typical truss joint design that enables EVA assembly while satisfying structural requirements is also presented. Preliminary results indicate that assembly rates in excess of one strut/min are achievable. Author

# **A89-46573 RESULTS AND PERSPECTIVES IN THE FIELD OF SPACE MATERIALS SCIENCE (SMS)**

L. L. REGEI (AN SSSR, Institut Kosmicheskikh Issledovani, Moscow, USSR) Space Science Reviews (ISSN 0038-6308), vol. 48, no. 1-2, 1988, p. 169-186. refs

Copyright

The effects of microgravity (MG) on the physical behavior of materials are discussed, reviewing the results of recent theoretical investigations and space experiments. The major topics addressed include theoretical models of crystal growth and mass and heat transfer, numerical simulations of liquid formation and motion under MG conditions, the MG growth of semiconductors, the MG solidification of metallic materials, the MG processing of glasses, crystal growth from liquid solutions in MG, and space MG instrumentation. Consideration is given to short-term tower, airborne, or rocket-borne MG experiments; electrophoresis under MG; experiments at above 1 g; and plans for further extensive investigations on the Soviet and NASA-international space stations. T.J.

# **A89-47134# ROUTING AND SCHEDULING FOR SPACE TRANSPORTATION TO MARS AND THE OUTER PLANETS**

G. LIST (Rensselaer Polytechnic Institute, Troy, NY) and R. RAESS AIAA, ASME, SAE, and ASCE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 9 p. refs (AIAA PAPER 89-2664) Copyright

This paper presents new and emerging concepts about the routing and scheduling of spaceships on voyages through the solar system focusing on transportation between Mars and earth. It is shown that the choice of route and schedule hinges heavily on the extent to which travel time can be traded off against energy consumption. The orbital central angle between perigee of the transfer orbit and spaceship position 1 and the travel time is a key variable. Opportunities for future research are discussed. Author

**A89-48565\*#** Stanford Univ., CA.

# **REVIEW OF ELECTRODYNAMIC TETHERS FOR SPACE PLASMA SCIENCE**

PETER M. BANKS (Stanford University, CA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 26, July-Aug. 1989, p. 234-239. Previously cited in issue 09, p. 1296, Accession no. A89-25535. refs

(Contract NAS8-36812)

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# **A89-48707 EARTH OBSERVATION FROM THE POLAR PLATFORM - A NEW ERA**

N. DE VILLIERS (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 23-27.

Copyright

This paper indicates how scenarios can be constructed around the ESA and NASA polar platforms of the International Space Station by deploying integrated sets of instruments on the different platforms in a coordinated manner with instruments contributed by and through the earth observation offices of the Space Station partners. Ways in which the expendable ESA polar platform can be used in an integrated series of missions to provide data in an ongoing and continuous manner to meet European needs are elaborated. The payloads required are described and the way such an overall program would evolve from the present programs and complement the other future programs is outlined. The role that international earth observation coordination can play is also indicated. Author

# **A89-48880# THE REGULATION OF COMMERCIAL SPACE ACTIVITIES BY THE NON-GOVERNMENTAL ENTITIES IN SPACE LAW**

KUNIHICO TATSUZAWA (Chuo Gakuin University, Tokyo, Japan) IN: Colloquium on the Law of Outer Space, 31st, Bangalore, India, Oct. 13, 14, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 341-348. refs

Copyright

The regulation of commercial space activities on the international level is discussed, focusing on the problems of legality and jurisdiction. The applicability of the principle of freedom of outer space and the common interest principle in commercial space activities is examined. Consideration is given to the problems of intellectual property and inventions in space, product liability in space, and governmental aid in space industrialization. R.B.

# **A89-49374 SPACE INDUSTRIALISATION - A NEW PERSPECTIVE**

MARK HEMPSELL Spaceflight (ISSN 0038-6340), vol. 31, July 1989, p. 224-227. refs

Copyright

Recent studies of the long-term development of space technology suggest that the industrialization of space is far more than just another investment; it is crucial for the continued survival of technical civilization. The economic viability of a space factory is assessed with reference to the extent and efficiency of the space infrastructure in place. Currently, new space infrastructure elements are introduced every 15 to 20 years. The pace of the Western space effort needs to be accelerated to get anywhere

## 15 MISSIONS, TETHERS, AND PLATFORMS

near its target. The NASA Post-Apollo program offers a vision of lunar bases and manned flight to Mars. C.E.

### **A89-49464#** University of Central Florida, Orlando. **AN OPTIMIZED SPACE STATION TETHERED ELEVATOR DESIGN**

MICHAEL H. HADDOCK and LOREN A. ANDERSON (Central Florida, University, Orlando, FL) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 10 p. Research supported by NASA and Universities Space Research Association. refs (AIAA PAPER 89-2106) Copyright

The optimized conceptual engineering design of a Space Station tethered elevator is presented. The tethered elevator is an unmanned, mobile structure which operates on a ten-kilometer tether spanning the distance between the Space Station and a tethered platform. Its capabilities include providing access to residual gravity levels, remote servicing, and transportation to any point along a tether. Emphasis is placed on the elevator's structural configuration and three major subsystem designs. First, the design of elevator robotics used to aid in elevator operations and tethered experimentation is presented. Second, the design of drive mechanisms used to propel the vehicle is discussed. Third, the design of an on board self-sufficient power generation and transmission system is addressed. Author

### **A89-50805#** **OVERVIEW OF ESA TETHER ACTIVITIES**

K. REINHARTZ (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) AIAA, NASA, Agenzia Spaziale Italiana, and ESA, International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989. 4 p. (AIAA PAPER 89-1617) Copyright

The paper describes the current and planned activities of the European Space Agency in the field of tethered systems. A review is made of future ESA programs and a preliminary assessment of the applicability of tethers to their programs is made. There are two obvious applications in the medium term but in the longer term considerable interest exists, mainly in Space Science, Microgravity Research, and Space Station Operations. A program of studies and technology development has started which could eventually lead to flight demonstration of a European tether facility and scientific or space operation experiments at the end of the nineties. Author

### **A89-51435** **STAGES IN THE DEVELOPMENT OF LOW EARTH ORBIT TOURISM**

PATRICK Q. COLLINS (Imperial College of Science, Technology and Medicine, London, England) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 3, 1989, p. 315-323. refs Copyright

It is known that the popular demand for short passenger flights into low earth orbit would be significant even at very high prices, and market research suggests that as the price of such a service fell towards \$10,000, the number of passengers might grow as high as one million per year. Such a level of activity would be very significant for the development of the space industry, requiring much higher launch rates and lower costs than currently envisaged for other purposes. If such a service is initiated, the range of services offered to passengers will develop progressively through a number of stages as traffic increases. The paper considers the sequence of developments that can be foreseen - from short sub-orbital space-flights in the early stages, to extended visits to large-scale orbiting facilities, such as hotels and even theme parks, some decades later - and discusses certain features of each stage, as well as some of their implications for the growth of a commercial space industry. Author

### **A89-51829** **SPACE COMMERCE; PROCEEDINGS OF THE SECOND INTERNATIONAL CONFERENCE AND EXHIBITION ON THE COMMERCIAL AND INDUSTRIAL USES OF OUTER SPACE, MONTREUX, SWITZERLAND, FEB. 21-25, 1988**

New York, Gordon and Breach Science Publishers, 1988, 490 p. For individual items see A89-51830 to A89-51859.

Copyright

Papers concerning the commercial and industrial uses of outer space are presented, covering topics such as the commercial space market, satellite communications, materials processing in space, and commercial remote sensing. Consideration is given to ESA space commercialization efforts, computer mapping systems, applications for the Mir space station, power in space, European programs for space-based facilities, satellite launchers, Space Station payload accommodations, and epitaxial thin film growth in space. Other topics include contract research organizations, chemical analysis, cell biology, metallic compound manufacturing experiments during the D-1 mission, manufacturing in LEO, the economics of space business, satellite liability insurance, the export of space technology, and trends in European and Soviet space technology. R.B.

### **A89-51834** **SPACE BUSINESS - THE NEXT INDUSTRIAL FRONTIER**

ROBERT ANDERSON (Rockwell International Corp., Pittsburgh, PA) IN: Space Commerce; Proceedings of the Second International Conference and Exhibition on the Commercial and Industrial Uses of Outer Space, Montreux, Switzerland, Feb. 21-25, 1988. New York, Gordon and Breach Science Publishers, 1988, p. 75-83. Copyright

Issues related to the transition from terrestrial-based to space-based commercial activities are discussed, emphasizing international cooperation and competition. It is suggested that there are three basic steps necessary for this transition: the development of a broader scientific and technical base, ensuring reliable, predictable, and cost-effective access to space, and constructing a space platform, such as the Space Station. R.B.

### **A89-51843** **INDUSTRIAL SPACE FACILITY**

JOSEPH P. ALLEN (Space Industries, Inc., Houston, TX) IN: Space Commerce; Proceedings of the Second International Conference and Exhibition on the Commercial and Industrial Uses of Outer Space, Montreux, Switzerland, Feb. 21-25, 1988. New York, Gordon and Breach Science Publishers, 1988, p. 181-200. Copyright

The Industrial Space Facility (ISF) is a commercial project with the long-range goal of design, construction, operation, and ownership of a facility that will complement the infrastructure of the U.S. space program, including the International Space Station. The near-term plan is to place the ISF, a man-tended space platform, into commercial operation on a lease-for-service basis at the beginning of the next decade. The concept for the platform allows for growth both in size and function, allowing the ISF to become a prototype industrial park in space. The ISF is designed to reach full operational status with a single Space Shuttle launch. Individual ISF modules will provide up to 12 kW of sustainable power along with cooling and telemetry capabilities in an environment of ultralow microgravity. Author

### **A89-51856** **PERSPECTIVES ON EARLY USE OF LOW EARTH ORBIT FOR SPACE MANUFACTURING**

B. L. HOEKSTRA (Clarkson University, Potsdam, NY) IN: Space Commerce; Proceedings of the Second International Conference and Exhibition on the Commercial and Industrial Uses of Outer Space, Montreux, Switzerland, Feb. 21-25, 1988. New York, Gordon and Breach Science Publishers, 1988, p. 385-392. Copyright

Specific research projects directed toward commercial manufacturing in LEO are reviewed. The topics include solution growth of room temperature IR detectors, solution growth of

inorganic and organic crystals for second-harmonic devices, liquid-encapsulated melt-zone growth of GaAs, and directional solidifications of CdTe. Other projects are global mass flux measurements in vapor transport, local thermofluid field effects in vapor transport of Hg halide, zeolite precipitation in microgravity, and crystal characterizations using synchrotron X-ray topography.  
R.B.

**A89-53299#**

**A NEW ROLE FOR FREEDOM**

P. M. BANKS and C. C. ISON (Stanford University, CA) *Aerospace America* (ISSN 0740-722X), vol. 27, Sept. 1989, p. 30-32, 34.  
Copyright

An operational earth monitoring system for the Space Station Freedom is proposed. The system is designed to provide nations fast and frequent data on land use, population growth, and anthropogenic changes due to effluents. Various other uses for remote sensing data and the use of Freedom for operational remote sensing are discussed.  
I.F.

**A89-53344\*** Alabama Univ., Huntsville.

**ELECTROSTATIC CHARGING OF SPACECRAFT IN RESPONSE TO ELECTRON BEAM INJECTION**

NAGENDRA SINGH and K. S. HWANG (Alabama, University, Huntsville) *Physica Scripta* (ISSN 0031-8949), vol. 40, no. 3, Sept. 1989, p. 295-301. refs  
(Contract NAS8-37107; NAGW-1563)  
Copyright

Electron beam injections from spacecraft now constitute a major activity in space research. Here, the charging level of a conducting surface when an electron beam is injected from it is investigated. Injections into both vacuum and an ambient plasma are considered. When a Maxwellian beam is injected into vacuum, the surface changes to a potential much greater than the average beam energy. The dependence of this excess is examined by considering beams with water-bag types of velocity distribution functions in which no electron has a velocity  $V(\max)$  above a certain value. The electric field distribution in the electron sheath near the surface is determined by the pressure distribution. Thus, the surface potential is determined not only by  $V(\max)$  but by all the beam parameters. The ambient plasma reduces the charging level and causes an oscillation in the surface potential. The oscillation frequency is the electron-plasma frequency associated with the ambient plasma.  
C.D.

**N89-20156# European Space Agency, Paris (France).  
THE CLUSTER MISSION: SCIENTIFIC AND TECHNICAL  
ASPECTS OF THE INSTRUMENTS**

T. D. GUYENNE, comp. Oct. 1988 103 p  
(ESA-SP-1103; ISSN-0379-6586; ETN-89-94132) Avail: NTIS HC A06/MF A01; ESA Publications Div., ESTEC, Noordwijk, Netherlands, \$10 US or 25 Dutch guilders

The Cluster mission, magnetic field measuring, wave experiments, electric field measurement, ionospheric sounding, particle spectrometry, particle imaging detectors, and spacecraft potential control are discussed.

ESA

**N89-21731\*#** South Carolina Univ., Columbia. Dept. of Mechanical Engineering.

**SMALL EXPENDABLE DEPLOYER SYSTEM MEASUREMENT ANALYSIS**

CONNIE K. CARRINGTON In Alabama Univ., Research Reports: 1988 NASA/ASEE Summer Faculty Fellowship Program 16 p Dec. 1988

Avail: NTIS HC A89/MF E03 CSCL 22/2

The first on-orbit experiment of the Small Expendable Deployer System (SEDS) for tethered satellites will collect telemetry data for tether length, rate of deployment, and tether tension. The post-flight analysis will use this data to reconstruct the deployment history and determine dynamic characteristics such as tether shape and payload position. Linearized observability analysis has

determined that these measurements are adequate to define states for a two-mass tether model, and two state estimators were written.  
Author

**N89-22780\*#** Smithsonian Astrophysical Observatory, Cambridge, MA.

**THEORETICAL INVESTIGATION OF EM WAVE GENERATION AND RADIATION IN THE ULF, ELF, AND VLF BANDS BY THE ELECTRODYNAMIC ORBITING TETHER Final Report, 1 May 1987 - 31 Jul. 1988**

ROBERT D. ESTES and MARIO D. GROSSI Mar. 1989 74 p  
(Contract NAG8-638)  
(NASA-CR-181560; NAS 1.26:181560) Avail: NTIS HC A04/MF A01 CSCL 20/14

The problem of electromagnetic wave generation by an electrodynamic tethered satellite system is important both for the ordinary operation of such systems and for their possible application as orbiting transmitters. The tether's ionospheric circuit closure problem is closely linked with the propagation of charge-carrying electromagnetic wave packets away from the tethered system. Work is reported which represents a step towards a solution to the problem that takes into account the effects of boundaries and of vertical variations in plasma density, collision frequencies, and ion species. The theory of Alfvén wave packet generation by an electrodynamic tethered system in an infinite plasma medium is reviewed, and brief summary of previous work on the problem is given. The consequences of the presence of the boundaries and the vertical nonuniformity are then examined. One of the most significant new features to emerge when ion-neutral collisions are taken into account is the coupling of the Alfvén waves to the fast magnetosonic wave. This latter wave is important, as it may be confined by vertical variations in the Alfvén speed to a sort of leaky ionospheric wave guide, the resonances of which could be of great importance to the signal received on the Earth's surface. The infinite medium solution for this case where the (uniform) geomagnetic field makes an arbitrary angle with the vertical is taken as the incident wave-packet. Even without a full solution, a number of conclusions can be drawn, the most important of which may be that the electromagnetic field associated with the operation of a steady-current tethered system will probably be too weak to detect on the Earth's surface, even for large tethered currents. This is due to the total reflection of the incident wave at the atmospheric boundary and the inability of a steady-current tethered system to excite the ionospheric wave-guide. An outline of the approach to the numerical problem is given. The use of numerical integrations and boundary conditions consistent with a conducting Earth is proposed to obtain the solution for the horizontal electromagnetic field components at the boundary of the ionosphere with the atmospheric cavity.  
Author

**N89-23493\*#** National Aeronautics and Space Administration, John F. Kennedy Space Center, Cocoa Beach, FL.

**AGENDA OF THE FOURTH ANNUAL SUMMER CONFERENCE, NASA/USRA UNIVERSITY ADVANCED DESIGN PROGRAM**

Jun. 1988 105 p Prepared for presentation at Cocoa Beach, FL, 13-17 Jun. 1988; sponsored in part by AIAA  
(Contract NGT-21-002-080; NGT-80001)  
(NASA-TM-101750; NAS 1.15:101750) Avail: NTIS HC A06/MF A01 CSCL 22/1

Presentations given by the participants at the fourth annual summer conference of the NASA/USRA University Advanced Design Program are summarized. The study topics include potential space and aeronautics projects which could be undertaken during a 20 to 30 year period beginning with the Space Station Initial Operating Configuration (IOC) scheduled for the early to mid-1990's. This includes system design studies for both manned and unmanned endeavors; e.g., lunar launch and landing facilities and operations, variable artificial gravity facility for the Space Station, manned Mars aircraft and delivery system, long term space habitat, construction equipment for lunar bases, Mars oxygen production system, trans-Pacific high speed civil transport, V/STOL aircraft concepts, etc.  
A.D.



## 15 MISSIONS, TETHERS, AND PLATFORMS

**N89-23512\*** Lockheed Missiles and Space Co., Palo Alto, CA. Research and Development Div.

### **SIRTF TELESCOPE INSTRUMENT CHANGEOUT AND CRYOGEN REPLENISHMENT (STICCR) STUDY Final Report, Nov. 1984 - Aug. 1985**

T. C. NAST, D. FRANK, C. K. LIU, R. T. PARMLEY, D. JAEKLE, H. BUILTEMAN, J. SCHMIDT, and T. H. K. FREDERICKING (California Univ., Los Angeles.) Aug. 1985 175 p (Contract NAS2-12051)

(NASA-CR-177380; NAS 1.26:177380; T-4277) Avail: NTIS HC A08/MF A01 CSCL 22/2

The Space Infrared Telescope Facility (SIRTF) is a long-life cryogenically cooled space-based telescope for infrared astronomy from 2 to 700 micrometers. SIRTF is currently under study by NASA-ARC (Reference AP) and planned for launch in approximately the mid 1990s. SIRTF will operate as a multiuser facility, initially carrying three instruments at the focal plane. It will be cooled to below 2 K by superfluid liquid helium to achieve radiometric sensitivity limited only by the statistical fluctuations in the natural infrared background radiation over most of its spectral range. The lifetime of the mission will be limited by the lifetime of the liquid helium supply, and baseline is currently to be 2 years. The telescope changes required to allow in-space replenishment of the 4,000-L superfluid helium tank was investigated. A preliminary design for the space services equipment was also developed. The impacts of basing the equipment and servicing on the space station were investigated. Space replenishment and changeout of instruments required changes to the telescope design. Preliminary concepts are presented. Author

**N89-24019\*** Florida Univ., Gainesville.

### **MICROGRAVITY PARTICLE REDUCTION SYSTEM**

VANESSA BRANDON, MICHELLE JOSLIN, LILI MATEO, and TRACEY TUBBS In its Advanced Space Design Program to the Universities Space Research Association and the National Aeronautics and Space Administration 20 p Jun. 1988

Avail: NTIS HC A12/MF A02 CSCL 22/1

The Controlled Ecological Life Support System (CELSS) project, sponsored by NASA, is assembling the knowledge required to design, construct, and operate a system which will grow and process higher plants in space for the consumption by crew members of a space station on a long term space mission. The problem of processing dry granular organic materials in microgravity is discussed. For the purpose of research and testing, wheat was chosen as the granular material to be ground into flour. Possible systems which were devised to transport wheat grains into the food processor, mill the wheat into flour, and transport the flour to the food preparation system are described. The systems were analyzed and compared and two satisfactory systems were chosen. Prototypes of the two preferred systems are to be fabricated next semester. They will be tested under simulated microgravity conditions and revised for maximum effectiveness. Author

**N89-24347\*** European Space Agency, Paris (France). Microgravity Program Management Office.

### **MICROGRAVITY PAYLOADS (APM AND MTFF)**

GUENTHER SEIBERT and PAUL CLANCY In its International Symposium on Europe in Space: The Manned Space System p 117-121 Oct. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The ESA microgravity program in materials sciences, physical chemistry, fluid dynamics and physics, biotechnology and biochemistry, and life sciences and radiation biology is discussed. Previous missions and the planned Columbus microgravity elements (attached pressure module, MTFF, polar platforms) are described. Payload studies for these elements are indicated. Microgravity outfitting of Columbus elements is reviewed. Critical resources are: rack space; power; toxic materials handling; crew time; and module outfitting rate and changeout. ESA

**N89-24348\*** European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).

### **SPACE SCIENCE USING COLUMBUS: MANNED SPACE SCIENCE**

H. OLTHOF In its International Symposium on Europe in Space: The Manned Space System p 123-124 Oct. 1988

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The scientific airlock of the Columbus attached pressurized module is described. Potential space science experiments and areas of research with the facility are suggested: wide field cameras; cosmic gamma ray burst detectors; total radiance measurement; active plasma diagnostics; and test and calibration of new technology. ESA

**N89-24380\*** Piano Spaziale Nazionale, Rome (Italy).

### **SCIENTIFIC UTILIZATION OF THE EUROPEAN SPACE INFRASTRUCTURE AND THE INTERNATIONAL SPACE STATION**

LUCIANO GUERRIERO and GIOVANNI RUM In ESA, International Symposium on Europe in Space: The Manned Space System p 411-414 Oct. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

Missions and research programs that could benefit from a permanent space infrastructure are indicated, including space sciences, materials processing, and microgravity effects. Italian contributions to the ESA in-orbit infrastructure program are described. ESA

**N89-24383\*** Preussag A.G., Erdoel und Erdgas, Hanover (Germany, F.R.).

### **INDUSTRIAL UTILIZATION OF MICROGRAVITY: PROBLEMS IN THE REALIZATION PHASE**

KARLHEINZ SCHOENEMANN In ESA, International Symposium on Europe in Space: The Manned Space System p 437-439 Oct. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

Crystal growth of compound semiconductor material is used to illustrate the potential of space processing and to explain why industrial companies are hesitant about using spaceborne techniques. The main reasons for this hesitation are the lack of knowledge of the effects of gravity on Earth, and the lack of information on the execution of experiments in space. ESA

**N89-24406\*** National Academy of Sciences - National Research Council, Washington, DC.

### **REPORT OF THE COMMITTEE ON A COMMERCIALY DEVELOPED SPACE FACILITY**

JOSEPH F. SHEA, H. GUYFORD STEVER, W. BOWMAN CUTTER, III, WOLFGANG H. DEMISCH, DANIEL J. FINK, ALEXANDER H. FLAX, HARRY C. GATOS, MARTIN E. GLICKSMAN, LOUIS J. LANZEROTTI, JOHN M. LOGSDON, III (George Washington Univ., Washington, DC.) et al. 1989 107 p

(Contract NASW-4003)

(NASA-CR-185383; NAS 1.26:185383) Avail: NTIS HC A06/MF A01 CSCL 14/2

Major facilities that could support significant microgravity research and applications activity are discussed. The ground-based facilities include drop towers, aircraft flying parabolic trajectories, and sounding rockets. Facilities that are intrinsically tied to the Space Shuttle range from Get-Away-Special canisters to Spacelab long modules. There are also orbital facilities which include recoverable capsules launched on expendable launch vehicles, free-flying spacecraft, and space stations. Some of these existing, planned, and proposed facilities are non-U.S. in origin, but potentially available to U.S. investigators. In addition, some are governmentally developed and operated whereas others are planned to be privately developed and/or operated. Tables are provided to show the facility, developer, duration, estimated gravity level, crew interaction, flight frequency, year available, power to

payload, payload volume, and maximum payload mass. The potential of direct and indirect benefits of manufacturing in space are presented. *Author*

**N89-24505\*** National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.  
**PROCEEDINGS OF THE GODDARD SPACE FLIGHT CENTER WORKSHOP ON ROBOTICS FOR COMMERCIAL MICROELECTRONIC PROCESSES IN SPACE**  
 3 Dec. 1987 210 p Workshop held in Greenbelt, MD, 2-3 Dec. 1987  
 (NASA-TM-101233; NAS 1.15:101233) Avail: NTIS HC A10/MF A02 CSCL 22/1

Potential applications of robots for cost effective commercial microelectronic processes in space were studied and the associated robotic requirements were defined. Potential space application areas include advanced materials processing, bulk crystal growth, and epitaxial thin film growth and related processes. All possible automation of these processes was considered, along with energy and environmental requirements. Aspects of robot capabilities considered include system intelligence, ROM requirements, kinematic and dynamic specifications, sensor design and configuration, flexibility and maintainability. Support elements discussed included facilities, logistics, ground support, launch and recovery, and management systems. *A.D.*

**N89-24820\*** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.  
**AN AUTOMATED PROTEIN CRYSTAL GROWTH FACILITY ON THE SPACE STATION Abstract Only**  
 MELODY HERRMANN In Tactical Weapons Guidance and Control Information Conference on Space and Military Applications of Automation and Robotics p 3 Jun. 1988  
 Avail: NTIS HC A05/MF A01 CSCL 22/1

The need is addressed for an automated Protein Crystal Growth experiment on the Space Station and how robotics will be integrated into the system design. This automated laboratory system will enable several hundred protein crystals to grow simultaneously in microgravity and will allow the major variables in protein crystal growth to be monitored and controlled during the experiment. Growing good quality crystals is important in determining the complete structure of the protein by X-ray diffraction. This information is useful in the research and development of medicines and other important medical and biotechnological products. Previous Protein Crystal Growth experiments indicate that the microgravity environment of space allows larger crystals of higher quality to be grown as compared to the same crystals grown on the ground. It is therefore important to have a laboratory in space where protein crystals can be grown under carefully controlled conditions so that a crystal type can be reproduced as needed. *Author*

**N89-25353\*** Naval Research Lab., Washington, DC. Computational Physics and Fluid Dynamics Lab.  
**TIME-DEPENDENT COMPUTATIONAL STUDIES OF FLAMES IN MICROGRAVITY Final Report, 1985 Dec. - 1988 Dec.**  
 ELAINE S. ORAN and K. KAILASANATH Jun. 1989 111 p  
 (Contract NASA ORDER C-80001-G)  
 (NASA-CR-182296; NAS 1.26:182296) Avail: NTIS HC A06/MF A01 CSCL 22/1

The research performed at the Center for Reactive Flow and Dynamical Systems in the Laboratory for Computational Physics and Fluid Dynamics, at the Naval Research Laboratory, in support of the NASA Microgravity Science and Applications Program is described. The primary focus was on investigating fundamental questions concerning the propagation and extinction of premixed flames in Earth gravity and in microgravity environments. The approach was to use detailed time-dependent, multispecies, numerical models as tools to simulate flames in different gravity environments. The models include a detailed chemical kinetics mechanism consisting of elementary reactions among the eight reactive species involved in hydrogen combustion, coupled to algorithms for convection, thermal conduction, viscosity, molecular

and thermal diffusion, and external forces. The external force, gravity, can be put in any direction relative to flame propagation and can have a range of values. A combination of one-dimensional and two-dimensional simulations was used to investigate the effects of curvature and dilution on ignition and propagation of flames, to help resolve fundamental questions on the existence of flammability limits when there are no external losses or buoyancy forces in the system, to understand the mechanism leading to cellular instability, and to study the effects of gravity on the transition to cellular structure. A flame in a microgravity environment can be extinguished without external losses, and the mechanism leading to cellular structure is not preferential diffusion but a thermo-diffusive instability. The simulations have also lead to a better understanding of the interactions between buoyancy forces and the processes leading to thermo-diffusive instability. *Author*

**N89-25431\*** New Technology, Inc., Huntsville, AL.  
**NEW ATMOSPHERIC SENSOR ANALYSIS STUDY Final Report**  
 K. G. PARKER 23 Feb. 1989 21 p  
 (Contract NAS8-36179)  
 (NASA-CR-183597; NAS 1.26:183597) Avail: NTIS HC A03/MF A01 CSCL 14/2

The functional capabilities of the ESAD Research Computing Facility are discussed. The system is used in processing atmospheric measurements which are used in the evaluation of sensor performance, conducting design-concept simulation studies, and also in modeling the physical and dynamical nature of atmospheric processes. The results may then be evaluated to furnish inputs into the final design specifications for new space sensors intended for future Spacelab, Space Station, and free-flying missions. In addition, data gathered from these missions may subsequently be analyzed to provide better understanding of requirements for numerical modeling of atmospheric phenomena. *Author*

**N89-26114\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.  
**FEASIBILITY OF REDUCED GRAVITY EXPERIMENTS INVOLVING QUIESCENT, UNIFORM PARTICLE CLOUD COMBUSTION**  
 HOWARD D. ROSS, LILY T. FACCA, ABRAHAM L. BERLAD, and VENKAT TANGIRALA (California Univ., San Diego.) Mar. 1989 40 p  
 (NASA-TM-101371; E-4417; NAS 1.15:101371) Avail: NTIS HC A03/MF A01 CSCL 22/1

The study of combustible particle clouds is of fundamental scientific interest as well as a practical concern. The principal scientific interests are the characteristic combustion properties, especially flame structure, propagation rates, stability limits, and the effects of stoichiometry, particle type, transport phenomena, and nonadiabatic processes on these properties. The feasibility tests for the particle cloud combustion experiment (PCE) were performed in reduced gravity in the following stages: (1) fuel particles were mixed into cloud form inside a flammability tube; (2) when the concentration of particles in the cloud was sufficiently uniform, the particle motion was allowed to decay toward quiescence; (3) an igniter was energized which both opened one end of the tube and ignited the suspended particle cloud; and (4) the flame proceeded down the tube length, with its position and characteristic features being photographed by high-speed cameras. Gravitational settling and buoyancy effects were minimized because of the reduced gravity environment in the NASA Lewis drop towers and aircraft. Feasibility was shown as quasi-steady flame propagation which was observed for fuel-rich mixtures. Of greatest scientific interest is the finding that for near-stoichiometric mixtures, a new mode of flame propagation was observed, now called a chattering flame. These flames did not propagate steadily through the tube. Chattering modes of flame propagation are not expected to display extinction limits that are the same as those for acoustically undisturbed, uniform, quiescent clouds. A low concentration of fuel particles, uniformly distributed in a volume, may not be flammable but may be made flammable, as was observed, through induced segregation processes. A theory was

## 15 MISSIONS, TETHERS, AND PLATFORMS

developed which showed that chattering flame propagation was controlled by radiation from combustion products which heated the successive discrete laminae sufficiently to cause autoignition.

Author

**N89-26115#** Manchester Univ. (England). Dept. of Engineering. **THE 1986 HOULDSWORTH MEMORIAL LECTURE: TAKING THE HIGH GROUND (THE COMMERCIAL EXPLOITATION OF SPACE)**

Oct. 1987 20 p Lecture held in Manchester, United Kingdom, 1986

(AERO-REPT-8706; ETN-89-94945) Avail: NTIS HC A03/MF A01

The history of space exploitation is reviewed and possibilities for commercialization of the space environment are discussed.

ESA

**N89-26885#** Teledyne Brown Engineering, Huntsville, AL. **ADVANCED SOLAR OBSERVATORY (ASO) ACCOMMODATIONS REQUIREMENTS STUDY Final Report**

May 1989 330 p

(Contract NAS8-37128)

(NASA-CR-183718; NAS 1.26:183718; SP89-MSFC-3225) Avail: NTIS HC A15/MF A02 CSCL 22/2

Results of an accommodations analysis for the Advanced Solar Observatory on Space Station Freedom are reported. Concepts for the High Resolution Telescope Cluster, Pinhole/Occultor Facility, and High Energy Cluster were developed which can be accommodated on Space Station Freedom. It is shown that workable accommodations concepts are possible. Areas of emphasis for the next stage of engineering development are identified.

Author

**N89-27887#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**NASA IN-HOUSE COMMERCIAL DEVELOPED SPACE FACILITY (CDSF) STUDY REPORT. VOLUME 1: CONCEPT CONFIGURATION DEFINITION**

L. J. DERYDER, H. D. CHIGER, D. D. DERYDER, K. N. DETWEILER, R. L. DUPREE, V. P. GILLESPIE, J. B. HALL, M. L. HECK, D. C. HERRICK, S. J. KATZBERG et al. 28 Apr. 1989 738 p

(NASA-TM-101586-VOL-1; NAS 1.15:101586-VOL-1) Avail: NTIS HC A99/MF E03 CSCL 22/2

The results of a NASA in-house team effort to develop a concept definition for a Commercially Developed Space Facility (CDSF) are presented. Science mission utilization definition scenarios are documented, the conceptual configuration definition system performance parameters qualified, benchmark operational scenarios developed, space shuttle interface descriptions provided, and development schedule activity was assessed with respect to the establishment of a proposed launch date.

Author

**N89-28023#** Illinois Univ., Chicago. Dept. of Mathematics Statistics and Computer Science.

**DESIGN OF EXPERIMENTS AND RELIABILITY MODELS Final Report, 1 Aug. 1985 - 31 Oct. 1988**

A. S. HEDAYAT and E. EL-NEWEHI 1 May 1989 51 p

(Contract AF-AFOSR-0320-85; AF PROJ. 2304) (AD-A209880; AFOSR-89-0772TR) Avail: NTIS HC A04/MF A01 CSCL 14/2

The research in design of experiments included the following areas: (1) efficient designs for experiments involving several factors; (2) efficient designs for repeated measurements models; (3) trade off in designs; (4) flexible orthogonal arrays; (5) efficient designs for comparing test treatments with controls; and (6) designs for collecting data through sampling. The research in reliability was mainly directed to the following areas: multistate reliability models; optimal assembly of coherent systems (both in the binary and multistate cases); redundancy importance and allocation of spares in coherent systems; closure properties of classes of life distributions; and optimal inspection policies.

GRA

**N89-26304#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

**LIFE SCIENCE RESEARCH OBJECTIVES AND REPRESENTATIVE EXPERIMENTS FOR THE SPACE STATION**

CATHERINE C. JOHNSON, ed., ROGER D. ARNO, ed., and RICHARD MAINS, ed. (Mains Associates, Moffett Field, CA.) Apr. 1989 299 p

(NASA-TM-89445; A-87160; NAS 1.15:89445) Avail: NTIS HC A13/MF A02 CSCL 06/3

A workshop was convened to develop hypothetical experiments to be used as a baseline for space station designer and equipment specifiers to ensure responsiveness to the users, the life science community. Sixty-five intra- and extramural scientists were asked to describe scientific rationales, science objectives, and give brief representative experiment descriptions compatible with expected space station accommodations, capabilities, and performance envelopes. Experiment descriptions include hypothesis, subject types, approach, equipment requirements, and space station support requirements. The 171 experiments are divided into 14 disciplines.

Author

**N89-26537#** Alabama Univ., Huntsville. Dept. of Mechanical Engineering.

**COORDINATION OF ADVANCED SOLAR OBSERVATORY (ASO) SCIENCE WORKING GROUP (SWG) FOR THE STUDY OF INSTRUMENT ACCOMMODATION AND OPERATIONAL REQUIREMENTS ON SPACE STATION Final Report, 1 Aug. 1987 - 30 Apr. 1989**

S. T. WU Oct. 1989 127 p

(Contract NAG8-682)

(NASA-CR-185371; NAS 1.26:185371) Avail: NTIS HC A07/MF A01 CSCL 22/1

The objectives are to coordinate the activities of the Science Working Group (SWG) of the Advanced Solar Observatory (ASO) for the study of instruments accommodation and operation requirements on board space station. In order to facilitate the progress of the objective, two conferences were organized, together with two small group discussions.

Author

**N89-28541#** Houston Univ., TX. Space Vacuum Epitaxy Center.

**PRIMARY RESEARCH EFFORTS ON EXPLORING THE COMMERCIAL POSSIBILITIES OF THIN FILM GROWTH AND MATERIALS PURIFICATION IN SPACE Annual Report, 1987-1988**

1989 16 p

(NASA-CR-184913; NAS 1.26:184913) Avail: NTIS HC A03/MF A01 CSCL 09/2

The progress made on research programs in the 1987 to 1988 year is reported. The research is aimed at producing thin film semiconductors and superconductor materials in space. Sophisticated vacuum chambers and equipment were attained for the epitaxial thin film growth of semiconductors, metals and superconductors. In order to grow the best possible epitaxial films at the lowest possible temperatures on earth, materials are being isoelectronically doped during growth. It was found that isoelectronically doped film shows the highest mobility in comparison with films grown at optimal temperatures. Success was also attained in growing epitaxial films of InSb on sapphire which show promise for infrared sensitive devices in the III-V semiconductor system.

E.R.

**N89-28554#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

**EXPANDABLE PALLET FOR SPACE STATION INTERFACE ATTACHMENTS Patent**

CLARENCE J. WESSELSKI, inventor (to NASA) 21 Feb. 1989 11 p Filed 21 Apr. 1988 Division of US-Patent-Appl-SN-829875, filed 13 Nov. 1986

(NASA-CASE-MSC-21117-2; US-PATENT-4,805,368; US-PATENT-APPL-SN-184233; US-PATENT-APPL-SN-829875; US-PATENT-CLASS-52-573; US-PATENT-CLASS-403-4;



US-PATENT-CLASS-403-30; US-PATENT-CLASS-248-DIG-1;  
US-PATENT-CLASS-52-648) Avail: U.S. Patent and Trademark  
Office CSCL 22/2

A foldable expandable pallet having a basic square configuration is disclosed. Each pallet is comprised of a plurality of struts, joined together by node point fittings to make a rigid structure. Some of the struts have hinge fittings and are spring loaded to permit collapse of the module for stowage and transport to a space station. Dimensions of the pallet are selected to provide convenient, closely spaced attachment points between the relatively widely spaced trusses of a space station platform. A pallet is attached to a truss at four points; one close fitting hole; two oversize holes; and a slot; to allow for thermal expansion/contraction and for manufacturing tolerances. Applications of the pallet include its use in rotary or angular joints; servicing of splints; with gridded plates; as an instrument mounting bases; and as a roadbed for a Mobile Service Center (MSC).

Official Gazette of the U.S. Patent and Trademark Office

**N89-28665\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, OH.

#### **MICROGRAVITY COMBUSTION SCIENCE: A PROGRAM OVERVIEW**

Jan. 1989 20 p  
(NASA-TM-101424; E-4524; NAS 1.15:101424) Avail: NTIS HC  
A03/MF A01 CSCL 12/1

The promise of microgravity combustion research is introduced by way of a brief survey of results, the available set of reduced gravity facilities, and plans for experimental capabilities in the Space Station era. The study of fundamental combustion processes in a microgravity environment is a relatively new scientific endeavor. A few simple, precursor experiments were conducted in the early 1970's. Today the advent of the U.S. space shuttle and the anticipation of the Space Station Freedom provide for scientists and engineers a special opportunity, in the form of long duration microgravity laboratories, and need, in the form of spacecraft fire safety and a variety of terrestrial applications, to pursue fresh insight into the basic physics of combustion. The microgravity environment enables a new range of experiments to be performed since buoyancy-induced flows are nearly eliminated, normally obscured forces and flows may be isolated, gravitational settling or sedimentation is nearly eliminated, and larger time or length scales in experiments become permissible. The range of experiments completed to date was not broad, but is growing. Unexpected phenomena have been observed often in microgravity combustion experiments, raising questions about the degree of accuracy and completion of our classical understanding and our ability to estimate spacecraft fire hazards. Because of the field's relative immaturity, instrumentation has been restricted primarily to high-speed photography. To better explain these findings, more sophisticated diagnostic instrumentation, similar to that evolving in terrestrial laboratories, is being developed for use on Space Station Freedom and, along the way, in existing microgravity facilities.

Author

**N89-28667\*** Techno System Developments, Naples (Italy).  
**TOLERABLE G-LEVEL FOR FLUID SCIENCE EXPERIMENTS**  
Final Report

Apr. 1987 85 p  
(Contract ESA-R-66-525)  
(TS-7-87; ETN-89-95197) Avail: NTIS HC A05/MF A01

The tolerable gravity levels for fluid and material science experiments, concerning space platforms, are investigated. The definition of the scenario of the gravity disturbances (topology and levels), the evaluation of the effects of the gravity disturbances on typical material and fluid science experiments, and the actions to be taken in order to reduce the spoiling effects of the gravity disturbances, are discussed. It is shown that the gravity level criteria, for orbiting microgravity platforms, is based on an oversimplification of the effects of the on-board gravity disturbances. Actions and recommendations for future activities are given.

ESA

**N89-28920\*** Joint Publications Research Service, Arlington, VA.  
**EARTH OBSERVATION PROGRAMS IN JAPAN**

TOMIFUMI GODAI In its JPRS Report: Science and Technology.  
USSR: Space. 16th International Congress of the International Society for Photogrammetry and Remote Sensing, Volume 2 p 175-185 31 Jan. 1989 Transl. into ENGLISH from International Archives of Photogrammetry and Remote Sensing (Kyoto, Japan), v. 27, pt. B11, 1988 p 434-442

Avail: NTIS HC A09/MF A02

The history of Japanese remote sensing involvement is discussed from the initial steps through the role in the upcoming Space Station polar platform.

B.G.

**N89-29361\*** Joint Publications Research Service, Arlington, VA.  
**MOTION OF TETHER DURING DEPLOYMENT AND  
RETRIEVAL OF TETHER SYSTEM IN ORBIT Abstract Only**

YE. M. LEVIN In its JPRS Report: Science and Technology.  
USSR: Space p 3 18 Jan. 1989 Transl. into ENGLISH from Kosmicheskoye Issledovaniye (Moscow, USSR), v. 26, no. 2, Mar. - Apr. 1988 p 199-208

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Some processes involved in deployment and retrieval of a weightless tether were studied. Considering the weight of the tether greatly complicates the problem. A new form is presented of the equation of motion, facilitating both analytic and numerical investigation of this case. The study is performed for two satellites connected by a tether of variable length in elliptical orbit, with the tether assumed to be very flexible but not elastic. The excitation of transverse oscillations of the tether as it is deployed or retrieved is studied. It is shown that as the tether is smoothly deployed, a quasisteady bending shape develops, while retrieval characteristically produces transverse oscillations.

Author

**N89-29428\*** Office of Naval Research European Office, FPO  
New York, NY.

#### **COSPAR (COMMITTEE ON SPACE RESEARCH) MEETS IN HELSINKI**

R. L. CAROVILLANO 19 Jan. 1989 7 p COSPAR 27th  
Plenary Meeting held in Helsinki, Finland, 18-29 Jul. 1988  
(AD-A209160; ONREUR-9-3-C) Avail: NTIS HC A02/MF A01  
CSCL 22/1

Proceedings of the 27th Plenary Meeting of the Committee on Space Research, held in Helsinki, are discussed. The discussion includes Soviet cosmonaut J. Romanenko's account of his epic space flight, interagency coordination of missions, and summaries of many papers under the heading of auroral topics.

GRA

**N89-29431\*** European Space Agency, European Space  
Research and Technology Center, ESTEC, Noordwijk  
(Netherlands).

#### **SPACE SCIENCE PAYLOADS**

H. OLTHOF In ESA, First European Workshop on Flight  
Opportunities for Small Payloads p 3-4 May 1989  
Copyright Avail: NTIS HC A09/MF A02; ESA Publications Div.,  
ESTEC, Noordwijk, Netherlands, 40 Dutch guilders

A survey was made requesting an indication of interest and letters of intent to propose experiments for Eureka flights in the domain of space sciences. A total of 67 letters have been received. The large response and the quality of the proposals shows that there is no shortage of ingenuity of the scientific community to propose valuable experiments. Subjects include gamma ray and X-ray astronomy, solar system cosmic rays, solar physics, aurora measurements and planetary entry probes.

ESA

**N89-29436\*** European Space Agency, European Space  
Research and Technology Center, ESTEC, Noordwijk  
(Netherlands).

#### **TECHNOLOGY DEMONSTRATION PAYLOADS**

G. REIBALDI In ESA, First European Workshop on Flight  
Opportunities for Small Payloads p 25-30 May 1989  
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ESTEC, Noordwijk, Netherlands, 40 Dutch guilders

The content, status and planning of the present and future

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technology demonstration program are presented. The space engineering technologies discussed include solid state micro accelerometer, aluminum coating, collapsible tube mast, inflatable structures, attitude sensor package, liquid gauging technology and GaAs solar panels. ESA

**N89-29449#** Dornier System G.m.b.H., Friedrichshafen (Germany, F.R.).

### **RAUMKURIER: A MISSION OPPORTUNITY FOR RETRIEVABLE MICROGRAVITY EXPERIMENTS**

M. EYB, R. HENKEL, and H. DOUKAS (Deutsche Gesellschaft fuer Luft- und Raumfahrt, Cologne, Germany, F.R.) In ESA, First European Workshop on Flight Opportunities for Small Payloads p 101-105 May 1989

Copyright Avail: NTIS HC A09/MF A02; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 40 Dutch guilders

A low cost flight opportunity with reentry capability for autonomous experiments is described. The carrier can be launched with Ariane and other transportation systems. System and subsystem design account for low cost, first flight late 1991 and a mission duration of 7 days. The payloads it can carry are significant for the preparation of the Columbus utilization. ESA

**N89-29478#** Naples Univ. (Italy).

### **THE USE OF THE TETHERED SATELLITE SYSTEM TO PERFORM LOW DENSITY AEROTHERMODYNAMICS STUDIES**

GIOVANNI M. CARLOMAGNO, LUIGI DELUCA, PAUL M. SIEMERS, and GEORGE M. WOOD, JR. (National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.) 1988 5 p Presented at the 16th International Symposium on Space Technology and Science, Sapporo, Japan, 22-24 May 1988 Sponsored in part by NASA

(NASA-CR-185837; NAS 1.26:185837; ETN-89-95203) Avail: NTIS HC A01/MF A01 CSCL 22/2

The Tethered Satellite System (TSS) is a cooperative space system development activity of the U.S.A. and Italy. It is comprised of the Tether Satellite (TS) and the deployer. Within TSS, the Shuttle Tethered Aerothermodynamic Research Facility (STARFAC) concept has the potential to provide access to vast portions of the upper atmosphere for atmospheric and aerothermodynamic research. The feasibility and capability of the TSS to operate as a continuous open wind tunnel and to perform low density aerothermodynamic studies are investigated. This is accomplished through a modified version of the TS simulation program (SKYHOOK). The results indicate that STARFAC concept is both feasible and practical. The TS can go below 100 km but, if thrust is used, large velocity variation ( $\Delta V$ ) maneuvers and an altitude control are required; if a satellite lift is considered, large tether tension is produced and an altitude control is required. ESA

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### **OPERATIONS SUPPORT**

Includes descriptions of models, analyses and trade studies of maneuvers, performance, Logistics support, and EVA and/or IVA servicing requirements of systems such as the OMV and OTV, and experiments.

**A89-36725#**

### **FLEEING FREEDOM**

RICHARD DEMEIS Aerospace America (ISSN 0740-722X), vol. 27, May 1989, p. 38-41. Copyright

Studies conducted to formulate escape system requirements and alternatives for the crew of the NASA Space Station Freedom are discussed. A rescue craft, either orbitally or terrestrially based, may become indispensable even without overwhelmingly favorable cost/benefit analyses because of the extreme public-relations risk associated with spacecrew deaths due to accidents. While

NASA-Johnson is developing ballistic escape module concepts, those of NASA-Langley take the form of lifting bodies. Even with a rescue vehicle's incorporation, efforts will be made to augment the Space Station's designed-in safe-haven component. O.C.

**A89-38243**

### **ORBITAL SERVICING VEHICLE**

TOHRU TAKAGI, NAOKI TSUYA, and HIROAKI OBARA (Mitsubishi Electric Corp., Space Systems Dept., Kamakura, Japan) In: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1591-1596.

Copyright

This paper presents the results of a concept definition study of the Orbital Servicing Vehicle (OSV). The initial OSV will be operated based on the Space Station. The major missions of the initial OSV are (1) deployment and retrieval of unmanned co-orbiting platform; (2) changeout payloads on platform; (3) exchange of failed equipments of platform; (4) resupply of consumable to platform; and (5) supply of materials to and retrieval of products from mission payloads. To perform above missions accurately, the initial OSV has a capability of automatic maneuver including automatic rendezvous and docking. It has also a remote manipulator system. Author

**A89-43140**

### **ASTRONAUT TRAINING SIMULATORS FOR THE SPACE STATION PROGRAM**

ANKUR R. HAJARE and GEORGE E. STARK (Mitre Corp., Houston, TX) In: 1988 Annual Summer Computer Simulation Conference, 20th, Seattle, WA, July 25-28, 1988, Proceedings. San Diego, CA, Society for Computer Simulation International, 1988, p. 547-553. refs

(Contract F19628-86-C-0001)

Copyright

NASA's Space Station Training Facility (SSTF), which will be used to train astronauts and ground systems personnel, is described. In particular, the SSTF will be used to train crews for normal and contingency operations using both generic and Station configuration-specific procedures, to provide on-line support of the Station by evaluating anomalies and developing contingency procedures, and to verify the on-orbit software through its use in simulators. The various types of simulators to be included in the SSTF are described. These include the Space Station systems trainers, the Station proximity operations trainer, ground systems trainers, and a computer aided instructional trainer. K.K.

**A89-43720\*** National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, TX.

### **SPACE STATION INITIAL OPERATIONAL CONCEPT (IOC) OPERATIONS AND SAFETY VIEW - AUTOMATION AND ROBOTICS FOR SPACE STATION**

WILLIAM V. BATES, JR. (NASA, Johnson Space Center, Houston, TX) In: Space - A new community of opportunity; Proceedings of the Thirty-fourth Annual AAS International Conference, Houston, TX, Nov. 3-5, 1987. San Diego, CA, Univelt, Inc., 1988, p. 349-354.

(AAS PAPER 87-667) Copyright

The automation and robotics requirements for the Space Station Initial Operational Concept (IOC) are discussed. The amount of tasks to be performed by an eight-person crew, the need for an automated or directed fault analysis capability, and ground support requirements are considered. Issues important in determining the role of automation for the IOC are listed. R.B.

**A89-43721\*** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

### **EVA SPACE CONSTRUCTION - EXPERIENCE AND FUNDAMENTAL ISSUES**

WALTER L. HEARD, JR., JUDITH J. WATSON (NASA, Langley Research Center, Hampton, VA), JERRY L. ROSS, SHERWOOD C. SPRING, and KATHRYN A. HAVENS (NASA, Johnson Space Center, Houston, TX) In: Space - A new community of opportunity;

Proceedings of the Thirty-fourth Annual AAS International Conference, Houston, TX, Nov. 3-5, 1987. San Diego, CA, Univelt, Inc., 1988, p. 395-414; Discussion, p. 415-417. refs  
Copyright

Results are presented from EVA space construction studies performed in 1 g, simulated 0 g, and on-orbit. The studies include tests of astronaut participation on the Mobile Work Station concept and the Swing-Arm Beam Erector. Also, results from the Experimental Assembly of Structures in EVA and the Assembly Concept for Construction of Erectable Space Structure programs are summarized. EVA construction applications for the Space Station are discussed and construction scenarios are developed.

R.B.

#### AB9-44646#

##### THE EUROPEAN SPACE SUIT AND EXTRA VEHICULAR ACTIVITIES - NEW OPPORTUNITIES FOR MANNED SPACE ACTIVITIES IN EUROPE

AKE INGEMAR SKOOG, MARTIN DIENER, REINHARD LOEWENS, ROLAND VAETH, and EBERHARD ACHTERMANN  
Dornier Post (ISSN 0012-5563), no. 2, 1989, p. 100-105.

Copyright

The EVA system developed by EVA, and the European space suit which will be a key element in the system, are discussed. The Suit Enclosure Module and Life Support Module of the Space Suit are described, the major functions of the EVA life support system are shown, and the EVA life support system module baseline is diagrammed. The Information and Communication Module which provides information and control function to the EVA astronaut is discussed.

C.D.

#### AB9-45793

##### SURVEY OF SOVIET SPACE WELDING TECHNOLOGY DEVELOPMENT

J. K. WATSON, D. W. DICKINSON, and S. I. ROKHLIN (Ohio State University, Columbus) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 820-831. refs

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Soviet engineers clearly recognize the potential value of welding for maintenance, repair, and fabrication of structures in space. The development of this technology has followed a steady path for more than twenty years. This paper traces that development from the earliest days to the present. Research into a number of joining processes has been conducted in the laboratory, aboard research aircraft, and on-orbit. The highlight of the program to date has been extravehicular activity demonstration experiments.

Author

#### AB9-45796

##### THE ROLE OF WELDING IN SPACE MAINTENANCE AND REPAIR

J. K. WATSON and D. W. DICKINSON (Ohio State University, Columbus) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 844-851. refs

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The nature of future space missions will result in increased incidence of degradation, damage, and wear of critical or expensive hardware. In many terrestrial applications, welding provides the only means of making high quality, economical repairs in a timely fashion. This paper considers the future role of welding in space with particular emphasis on a number of factors which will require careful consideration as the development of this technology proceeds.

Author

#### AB9-45813

##### SPACE OPERATIONS - CARE AND HANDLING OF REMAINS

C. R. BEAUCHEMIN (USAF, Engineering and Services Center, Tyndall AFB, FL) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque,

NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 1064-1070.

Copyright

Consideration is given to the design and development of facilities and equipment for the care and handling of human remains (corpses) in space operations. The options for holding unembalmed remains and the space and equipment requirements for an embalming room on a spacecraft are discussed. The available alternatives for recovering remains in space, transferring remains from space to a preparation/holding facility or from one facility to another, and transporting remains from a space mortuary to earth are examined.

R.B.

#### AB9-45835

##### UNDERWATER TESTING IN THE DEVELOPMENT OF EVA SUPPORT SYSTEMS

R. E. EVANS (McDonnell Douglas Astronautics Co., Huntington Beach, CA) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 1331-1341.

Copyright

The ability to simulate realistic zero-g conditions on earth is of prime importance in determining if various orbital operations associated with extravehicular activity (EVA) can actually be accomplished in space. This paper assesses the methods and overall capabilities associated with underwater (UW) testing in the development of EVA support systems and associated manned EVA procedures. UW testing for this purpose is a powerful simulation tool that provides long duration, hands-on experience in a simulated zero-g environment. The ability to test design concepts in a realistic environment brings optimum solutions into focus faster and with greater confidence than analysis alone can provide. Included in this paper are various UW operations and their associated support systems that predict crew capabilities during actual EVA.

Author

#### AB9-47048#

##### RESUPPLY INTERFACE MECHANISM

FRANK G. GALLO, STEWART W. JACKSON, JOHN L. PULLEN, and BARNEY F. GORIN (Fairchild Space Co., Germantown, MD) AIAA, ASME, SAE, and ASCE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 15 p.

(AIAA PAPER 89-2732) Copyright

A satellite resupply interface mechanism (RIM) designed for maintainable spacecrafts is described, together with the results of its tests and of its participation in a satellite resupply demonstration/test at the NASA Johnson Space Center. The RIM functions are to provide mating guidance during the berthing/docking process, grasp and draw the two vehicles together, simultaneously connect all utility connectors (electrical, pneumatic, and fluid), and rigidize the interface. The unique aspect of the RIM is that it accomplishes the above docking task in a single action. The RIM Controller software is described, and diagrams of the RIM configuration and operations are presented.

I.S.

#### AB9-47327

##### FLIGHT CREW DISPLAYS FOR SPACE STATION PROXIMITY OPERATIONS

JOHN B. LAUGER, PAUL J. GEERY, and GEORGE L. MURPHY (McDonnell Douglas Astronautics Co., Huntington Beach, CA) IN: Aerospace Behavioral Technology Conference and Exposition, 7th, Anaheim, CA, Oct. 3-6, 1988. Proceedings, Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 21-27.

(SAE PAPER 881540) Copyright

This paper examines the requirements for the flight crew displays for Space Station proximity operations (i.e., operations within a range of 1 km from the Station), such as the control of manned and unmanned vehicles and robotics devices, final rendezvous and approach, berthing and docking, and separation and departure from the Station. Particular attention is given to the impact of the display device selection on the configuration of the



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Space Station cupolas. It is shown that, compared to CRTs, the flat-panel displays save over 450 lb of weight. The available state-of-the-art display technology is reviewed, and data are presented for a comparison of CRTs and active matrix LCD displays, as well as for various flat-panel technologies. I.S.

AB-47328

### EVA DESIGN INTEGRATION FOR SPACE STATION ASSEMBLY

REGINALD M. MACHELL, THEODORE F. GALLO, GREGORY R. BENNETT, and LORY A. HEFELE (McDonnell Douglas Astronautics Co., Space Station Div., Huntington Beach, CA) IN: Aerospace Behavioral Technology Conference and Exposition, 7th, Anaheim, CA, Oct. 3-6, 1988, Proceedings, Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 29-34. (SAE PAPER 881542) Copyright

EVA (extravehicular activity) will be a major aspect of the on-orbit assembly of the U.S. Space Station 'Freedom'. Under the auspices of NASA's Johnson Space Center, an EVA assembly integration plan has been developed. This plan provides a comprehensive approach to defining all the EVA assembly tasks and validating the systems and equipment designs for accomplishing these tasks on orbit. EVA tasks are traded off against the use of robotics devices. Task description sheets are used to compile pertinent data on all significant EVA tasks. An EVA task checklist is used to ensure consideration of all access and support equipment requirements. Evaluations of all EVA tasks are planned and scheduled, using the WETF (Weightless Environment Training Facility) at JSC or other test facilities as appropriate. This comprehensive approach provides confidence in the successful EVA assembly of the Space Station. Author

AB-48170#

### MAINTAINABILITY ALLOCATIONS THROUGH OPERATIONAL AVAILABILITY ANALYSIS

W. THAD MAULDIN, M. DOUGLAS WILLIAMS, and MARVIN E. SMITH (Advanced Technology, Inc., Huntsville, AL) AIAA and NASA, Symposium on the Maintainability of Aerospace Systems, Anaheim, CA, July 26, 27, 1989, 6 p. (AIAA PAPER 89-0599) Copyright

A computer simulation model has been developed that permits the application of knowledge-based techniques to the analysis of space system operational availability. The application of that approach to the Advanced Launch System and Space Station Freedom is discussed, and results of a sample Space Station analysis are presented. Author

### AB-48574\*# Massachusetts Inst. of Tech., Cambridge. MOMENTS APPLIED IN THE ROTATION OF MASSIVE OBJECTS IN SHUTTLE EXTRAVEHICULAR ACTIVITY

D. COUSINS and D. L. AKIN (MIT, Cambridge, MA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 26, July-Aug. 1989, p. 293, 294, refs. (Contract NAS9-17266) Copyright

Experimentally derived applied moments are presented for Space Shuttle crew EVA mission rotations of objects more massive than the human body. These levels appear to be small fractions of physiological limits; horizontal and vertical shoulder strength limits greater than 50 Nm have been established for foot-restrained, pressure-suited subjects in simulated weightlessness. The reduced level in operational EVA may be due to unfamiliarity with manual control in true weightlessness. O.C.

### AB-49663\* Grumman Aerospace Corp., Bethpage, NY. MAKING ON-ORBIT STRUCTURAL REPAIRS TO SPACE STATION

HARRY S. HABER (Grumman Corp., Bethpage, NY) and ALBERTA QUINN (NASA, Marshall Space Flight Center, Huntsville, AL) Aerospace Engineering (ISSN 0736-2536), vol. 9, Aug. 1989, p. 20-24. Copyright

One of the key factors dictating the safety and durability of

the proposed U.S. Space Station is the ability to repair structural damage while remaining in orbit. Consequently, studies are conducted to identify the engineering problems associated with accomplishing structural repairs on orbit, due to zero gravity environment and exposure to extreme temperature variations. There are predominant forms of structural failure, depending on the metallic or composite material involved. Aluminum is the primary metallic material used in space vehicle applications. Welding processes on aluminum alloy structures were tested, resulting in final selection of electron beam welding as the primary technique for metallic material repair in Space. Several composite structure repair processes were bench-tested to define their applicability to on-orbit EVA requirements: induction heating prevailed. One of the unique problems identified as inherent in the on-orbit repair process is that of debris containment. The Maintenance Work Station concept provides means to prevent module contamination from repair debris and ensure the creation of a facility for crew members to work easily in a microgravity environment. Different technologies were also examined for application to EVA repair activities, and the concept selected was a spring-loaded, collapsible, box-like Debris Containment and Collection Device with incorporated fold-down tool boards and handholes in the front panel. C.E.

AB-51147

### FAILURE DETECTION AND IN ORBIT MAINTENANCE

B. GARBETT (British Aerospace, PLC, Space and Communications Div., Stevenage, England) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1988, p. 717-727. Copyright

Nondestructive testing has evolved over the decades from relatively simple procedures to the present-day sophisticated state-of-the-art technology. Lightweight structures intended for space use must be manufactured and tested to very high standards to meet the rigors of the launch and projected long-term life in GEO or LEO. How is it possible to ensure that products survive and perform very long periods in a space environment? This paper reviews this question and speculates from an NDT point of view. Author

AB-52697#

### TRACKING LASER RADAR FOR RENDEZVOUS DOCKING - A CONCEPTUAL DESIGN

H. ANEGAWA, Y. WAKABAYASHI (National Space Development Agency of Japan, Tsukuba Space Center, Japan), M. SHIMIZU, M. NAGAI, T. YASUGI (NEC Corp., Yokohama, Japan) et al. IN: AIAA Guidance, Navigation and Control Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers, Part 2, Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1590-1597, refs. (AIAA PAPER 89-3621) Copyright

A conceptual design study of an optical rendezvous docking sensor using a semiconductor laser radar was carried out as part of research aimed at the development of the rendezvous and docking technology. The time ranging method with four different frequencies was used to obtain a maximum range of several tens of kilometers and a ranging accuracy of 5 cm in the 1-km range. A range rate accuracy of 4 cm/s (1-20 km) using the subcarrier Doppler method, and of 1 cm/s (1km - 2 m) using the differential method was shown to be possible. A tracker laser radar was designed which is capable of measuring the LOS angle from the tracking angle with an accuracy of 0.1 deg. The relative attitude can be measured with a CCD image sensor with an accuracy of 0.6 to 0.2 deg; the maximum tracking rate is estimated at 1.8 deg/s. V.L.

AB-53297\*# National Aeronautics and Space Administration, Washington, DC.

### LOGISTICS COMES TO SPACE

GRANVILLE E. PAULES, III (NASA, Office of the Space Station,

Washington, DC) Aerospace America (ISSN 0740-722X), vol. 27, Sept. 1989, p. 26, 27, 34.

Copyright

Logistic difficulties associated with the Space Station Freedom are discussed. Proposed ground and on-orbit operations and procedures for supplying the Station are described. The transfer operations of supplies to the modules, the use of expendable launch vehicles for supplying the Station, and the use of EVA suits for assembling and servicing are considered. Ground support activities for resupplying and maintaining the spacecraft are examined. I.F.

**889-54699#**

#### PLANNING FOR SPACE STATION TESTING ON ORBIT

H. L. OLIVER, SR. (Boeing Aerospace, Huntsville, AL) IN: Aerospace Testing Seminar, 11th, Manhattan Beach, CA, Oct. 11-13, 1988, Proceedings. Mount Prospect, IL, Institute of Environmental Sciences, 1988, p. 267-275.

One of the Space Station's main goals is to design systems that are autonomous so that the Station's flight crew can effectively use their time in conducting science experiments. This objective leads to automatic fault detection, isolation, and reconfiguration to the orbital replacement unit level. Multilevel checkout is discussed as well as the multilevel test configuration, ground systems verification, rack level tests, module systems tests, module element integrated system checkout at launch site, and on-orbit test and verifications. K.K.

**889-20171#** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

#### A DEFINITION STUDY OF THE ON-ORBIT ASSEMBLY OPERATIONS FOR THE OUTBOARD PHOTOVOLTAIC POWER MODULES FOR SPACE STATION FREEDOM M.S. Thesis - Toledo Univ.

THOMAS J. SOURS Mar. 1989 89 p  
(NASA-TM-102006; E-4712; NAS 1.15:102006) Avail: NTIS HC A05/MF A01 CSCL 22B

A concept is described for the assembly of the outboard PV modules for Space Station Freedom. Analysis of the on-orbit assembly operations was performed using CADAM design graphics software. A scenario for assembly using the various assembly equipment, as currently defined, is described in words, tables and illustrations. This work is part of ongoing studies in the area of space station assembly. The outboard PV module and the assembly equipment programs are all in definition and preliminary design phases. An input is provided to the design process of assembly equipment programs. It is established that the outboard PV module assembly operations can be performed using the assembly equipment currently planned in the Space Station Freedom Program. Author

**889-20181#** Essex Corp., Huntsville, AL.

#### EXTRAVEHICULAR ACTIVITY AT GEOSYNCHRONOUS EARTH ORBIT Final Technical Report

NICHOLAS SHIELDS, JR., ARTHUR E. SCHULZE, GERALD P. CARR, and WILLIAM POGUE (CAMUS, Inc., Huntsville, AL.) 22 Jan. 1988 238 p  
(Contract NAS9-17779)  
(NASA-CR-172112; NAS 1.26:172112) Avail: NTIS HC A11/MF A02 CSCL 22B

The basic contract to define the system requirements to support the Advanced Extravehicular Activity (EVA) has three phases: EVA in geosynchronous Earth orbit; EVA in lunar base operations; and EVA in manned Mars surface exploration. The three key areas to be addressed in each phase are: environmental/biomedical requirements; crew and mission requirements; and hardware requirements. The structure of the technical tasks closely follows the structure of the Advanced EVA studies for the Space Station completed in 1986. Author

**889-21832#** Technische Univ., Berlin (Germany, F.R.). Inst. fuer Luft- und Raumfahrt.

#### SYSTEMS ANALYSIS OF THE EXTRATERRESTRIAL MAINTENANCE AND REPAIR OF SPACE SYSTEMS

[SYSTEMANALYSE DER EXTRATERRESTRISCHEN WARTUNG UND REPARATUR VON RAUMFAHRTSYSTEMEN]  
JENS LASSMANN 1 Jul. 1988 66 p In GERMAN; ENGLISH summary  
(ILR-MITT-201; ETN-89-93785) Avail: NTIS HC A04/MF A01

A system for extraterrestrial repair and maintenance is structured, and its functions and concepts are identified. A closer look at one of the concepts shows that the development of technologies such as docking, fueling, robotics and expert systems is necessary. The service system has to be more and more automated. The presented service concept cannot be considered as the very best conceivable, because too many uncertainties still exist. ESA

**889-22626#** Joint Publications Research Service, Arlington, VA. CONSTRUCTION IN WEIGHTLESSNESS

SERGEY DMITRIYEVICH GRISHIN and SERGEY VASILYEVICH CHEKALIN In its JPRS Report: Science and Technology. USSR: Space p 40-43 17 Aug. 1988 Transl. into ENGLISH from Problemy Osvoyeniya Kosmosa (Novoye v Zhizni, Nauka, Tekhnika: Seriya Kosmonavtika, Astronomiya) (Moscow, USSR), no. 1, Jan. 1988 p 36-44

Copyright Avail: NTIS HC A05/MF A01

Large-scale structures (LSSs), the conditions for their operation, the demands made on them, and the problems of deployment and assembly in orbit are discussed. B.G.

**889-23545#** Aerospace Corp., El Segundo, CA. Materials Sciences Lab.

#### SPACECRAFT CONTAMINATION EXPERIENCE

E. N. BORSON In NASA, Langley Research Center, NASA/SDIO Space Environmental Effects on Materials Workshop, Part 1 p 331-352 May 1989  
Avail: NTIS HC A16/MF A02 CSCL 22/2

Effective contamination control must encompass all aspects of ground and flight from design of the system through the end of mission life. Design systems are needed to minimize sensitivity to contamination, ease of cleaning, and contaminant production. Facilities and procedures are critical to maintaining cleanliness during ground operations. Flight operations should be planned so as to minimize contamination. More data from flights are required to assess the adequacy of designs and operations. Standards and specifications should include contamination control requirements. Author

**889-24376#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (Germany, F.R.). Space Operation Center.

#### THE MANNED SPACE LABORATORIES CONTROL CENTER (MSCC) AT DFVLR, OBERPFAFFENHOFEN, GERMANY, F.R.

JOACHIM KEHR In ESA, International Symposium on Europe in Space: The Manned Space System p 379-387 Oct. 1988  
Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The ESA approach for operating manned space laboratories is outlined. The ground segment and operational management structure are described. The manned space laboratories control center is presented. ESA

**889-24387#** European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).

#### GETTING READY FOR EVA

A. ACCENSI In its International Symposium on Europe in Space: The Manned Space System p 467-475 Oct. 1988  
Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The roles of astronauts and robots in space missions are discussed. The advantages of extravehicular activity (EVA) for

complex and contingency tasks is considered. The history and status of EVA programs conducted by ESA are summarized.

ESA

**N89-24388#** Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.).

**EVA INFORMATION SYSTEM: A MODERN WORKSTATION IN SPACE**

FRANZ PITTMANN, PIERRE LARROQUE, and STEPHANE BERTHIER (Avions Marcel Dassault-Breguet Aviation, Saint-Cloud, France) In ESA, International Symposium on Europe in Space: The Manned Space System p 477-483 Oct. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

Information and communication requirements for extravehicular activity (EVA) are identified. Man-machine interfaces for EVA are discussed, and the relative merits of astronauts and robots are compared. Technologies and techniques needed in an EVA workstation are considered, and it is argued that the required technologies exist and can be adapted to space conditions.

ESA

**N89-24832#** Moog, Inc., East Aurora, NY.  
**DISCONNECTS FOR SPACECRAFT SERVICING APPLICATIONS Abstract Only**

J. M. CARDIN In Tactical Weapons Guidance and Control Information Conference on Space and Military Applications of Automation and Robotics p 25 Jun. 1988

Avail: NTIS HC A05/MF A01 CSCL 09/2

The goals of U.S. space programs have created a need for large, complex, long-life spacecraft. This new generation of spacecraft has created a set of design drivers for their fluid systems. On-orbit erectability, maintainability, expandability, and resupply are system requirements that in many cases cannot be achieved using existing component technologies. Serviceable spacecraft fluid systems require disconnects to facilitate manual, remote, or automated on-orbit maintenance and resupply. In response to this need, disconnect technology that has improved performance characteristics such as pressure drop and spillage while maintaining configurations suitable for both manual and automated/robotic operation. The state of this technology is outlined, including data generated by in-house testing, in addition to industry and government evaluation.

Author

**N89-25244\*** National Aeronautics and Space Administration, Washington, DC.

**SPACE STATION OPERATIONS TASK FORCE. PANEL 1 REPORT: SPACE OPERATIONS AND SUPPORT SYSTEMS**

Dec. 1987 627 p (NASA-TM-101816; NAS 1.15:101816) Avail: Issuing Activity CSCL 22/1

The Space Operations and Support Systems Panel of the Space Station Operations Task Force was chartered to develop concepts for operations of the Space Station manned base and the platforms. These operations include those conducted in space to maintain the Space Station and platforms as usable facilities, operations to support users in their scientific, technological, or commercial research, operations of systems on the ground to support the space-based operations, and training of all personnel to perform their operations duties.

A.D.

## SPACE ENVIRONMENT

Includes description of the space environment and effects on Space Station subsystems. Includes requirements for Space Station to accommodate this environment.

**A89-34758**

**TOOL KIT FOR ANTENNAE AND THERMAL NOISE NEAR THE PLASMA FREQUENCY**

NICOLE MEYER-VERNET and CLAUDE PERCHE (Paris, Observatoire, Meudon, France) Journal of Geophysical Research (ISSN 0148-0227), vol. 94, March 1, 1989, p. 2405-2415. refs Copyright

The bases are provided for a straightforward derivation of either the quasi-thermal noise spectrum or the impedance of a given electric antenna near the plasma frequency, in order to calibrate or diagnose space plasmas. Analytical expressions and numerical results are presented for wire or sphere dipoles in an anisotropic plasma with one or two Maxwellian electron populations, encompassing the contribution of particles collected and/or emitted by the antenna surface. Modifications entailed by the use of one or more complex antenna geometries and by the presence of either a drifting or a magnetized plasma are noted.

O.C.

**A89-34816\*** Alabama Univ., Huntsville.

**PENETRATION AND RICOCHET PHENOMENA IN OBLIQUE HYPERVELOCITY IMPACT**

WILLIAM P. SCHONBERG (Alabama, University, Huntsville) and ROY A. TAYLOR (NASA, Marshall Space Flight Center, Huntsville, AL) AIAA Journal (ISSN 0001-1452), vol. 27, May 1989, p. 639-646. Previously announced in STAR as N88-18004. refs Copyright

An experimental investigation of phenomena associated with the oblique hypervelocity impact of spherical projectile on multisheet aluminum structures is described. A model that can be employed in the design of meteoroid and space debris protection systems for space structures is developed. The model consists of equations that relate crater and perforation damage of a multisheet structure to parameters such as projectile size, impact velocity, and trajectory obliquity. The equations are obtained through a regression analysis of oblique hypervelocity impact test data. This data shows that the response of a multisheet structure to oblique impact is significantly different from its response to normal hypervelocity impact. It was found that obliquely incident projectiles produce ricochet debris that can severely damage panels or instrumentation located on the exterior of a space structure. Obliquity effects of high-speed impact must, therefore, be considered in the design of any structure exposed to the meteoroid and space debris environment.

Author

**A89-34988**

**A FLUID MODEL OF HIGH VOLTAGE SPHERES IN THE IONOSPHERE**

T.-Z. MA (Utah State University, Logan) Planetary and Space Science (ISSN 0032-0633), vol. 37, Jan. 1989, p. 21-47. refs (Contract DNA001-87-C-0015; F49620-86-C-0109) Copyright

The Poisson equation and the time-dependent three-dimensional nonlinear fluid equations for  $O(+)$  and electrons have been solved in order to investigate the initial response of the ionosphere to positive high-voltage spheres. An electron density torus was shown to form around the spheres in the equatorial plane at early times. At later times, the outer edge of the torus elongates along the magnetic field, and the bulk of the region perturbed by the sphere is contained within a cylindrical volume.

R.R.



**AB9-36544\*** Lockheed Engineering and Sciences Co., Houston, TX.

**THE DETECTION AND OBSERVATION OF METEOROID AND SPACE DEBRIS IMPACT FEATURES ON THE SOLAR MAX SATELLITE**

J. L. WARREN, J. H. ALLTON, C. B. DARDANO, J. A. HOLDER, R. R. MARLOW (Lockheed Engineering and Sciences Co., Houston, TX), H. A. ZOOK (NASA, Johnson Space Center, Houston, TX), U. S. CLANTON (DOE, Waste Management Project Office, Las Vegas, NV), R. A. SCHULTZ (NASA, Goddard Space Flight Center, Greenbelt, MD) et al. IN: Lunar and Planetary Science Conference, 19th, Houston, TX, Mar. 14-18, 1988, Proceedings. Cambridge/Houston, TX, Cambridge University Press/Lunar and Planetary Institute, 1989, p. 641-657. refs  
(Contract NAS9-17900)

The results of optical observations on the entire population of impact pits and holes discovered on nearly all of the returned parts of the Solar Maximum Mission satellite are described. Some statistically significant new results on impact dynamics are obtained as well as new number vs. size distributions for craters and holes ranging from 40 to 900 microns. The local spacecraft geometric shielding corrections are calculated and applied to the data. Some selected compositional results are presented which indicate that the Space Shuttle can be a source of impacting debris. C.D.

**AB9-36696**

**THE MOTION OF CONTAMINANT WATER PLASMA CLOUDS ABOUT LARGE ACTIVE SPACE STRUCTURES**

D. E. HASTINGS and N. A. GATSONIS (MIT, Cambridge, MA) *Journal of Geophysical Research* (ISSN 0148-0227), vol. 94, April 1, 1989, p. 3729-3742. refs  
(Contract F19628-86-K-0018)  
Copyright

A model for the motion of contaminant water plasma clouds about a large space structure was developed assuming that the contaminant cloud consists of ions such as  $O^+$ ,  $H_2O^+$ , and  $H_3O^+$  and neutrals such as  $O$ ,  $H$ ,  $OH$ , and  $H_2O$ . The model includes emission of Alfvén waves from the cloud to carry current along the magnetic field. The numerical solution of the model equations examines the effects of Alfvén wave coupling, neutral water density, ion temperature, and initial conditions on the cloud motion. In all the cases considered, it is predicted that the backward moving clouds will develop fingerlike instabilities in the back-side of the clouds. The appearance of these instabilities is in agreement with experimental data. I.S.

**AB9-36773**

**MODELING OF ATMOSPHERE EXPLORER-D RETURN FLUX EXPERIMENT**

T. D. GORDON and W. R. SEEBAUGH (Science and Engineering Associates, Inc., Englewood, CO) *Geophysical Research Letters* (ISSN 0094-8276), vol. 16, April 1989, p. 299-302. refs  
Copyright

Codes for the prediction of spacecraft environments are currently in widespread use; however, few if any comparisons of code results with experimental measurements have been performed. In this paper the results are reported of calculations performed for the Atmosphere Explorer-D satellite at an altitude of approximately 250 km. Measurements of the atmospheric composition at the ram surface of the spacecraft were obtained by a closed source mass spectrometer before and during the operation of a return flux experiment in which a neon plume was directed into the spacecraft velocity vector. Calculations reproduced the measured fluxes of the ambient species immediately before and during the venting operation. The presence of the neon plume reduced the flux of ambient species reaching the detector. The model reproduced these trends and gave a range of calculated neon return flux with a mean approximately equal to the value derived from the measurements. Author

**AB9-38248**

**SUPPRESSION OF SURFACE POTENTIAL FORMATION ON SPACECRAFT**

HARUHISA FUJII, KOICHIRO NAKANISHI (Mitsubishi Electric Corp., Manufacturing Development Laboratory, Amagasaki, Japan), TOSHIO ABE, TOSHIKATSU OHMURA (Mitsubishi Electric Corp., Kamakura, Japan), and HIRONOBU NISHIMOTO (National Space Development Agency of Japan, Tsukuba) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1613-1619. refs  
Copyright

A study has been made of two methods to suppress surface potential formation on insulating materials on a spacecraft, this phenomenon being brought about by charged particles in space. To test the effectiveness of the suppression methods, a high-energy electron beam (a few keV to a few tens keV) was used which simulated geomagnetic substorm condition, and the potential induced by the accumulated charges on the insulating film was measured. One method was to coat a transparent conductive indium-tin oxide layer on Kapton film, the other was to cancel out the surface potential by ejecting Xe plasma from the neutralizer of an ion engine. Both methods are effective in terms of eliminating the surface potential electrostatically formed on spacecraft. Author

**AB9-38371**

**LABORATORY SIMULATION ON TWO DIMENSIONAL HIGH VOLTAGE SOLAR ARRAY (2D/HVSA) EXPERIMENT ONBOARD SFU**

HITOSHI KUNINAKA, AKIO USHIKAWA, MICHIOHITO NATORII, KEIJI TAKAHASHI, and KYOICHI KURIKI (Institute of Space and Astronautical Science, Sagami, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 2497-2502. refs  
Copyright

One of the main objectives of the 2D/HVSA Experiment in LEO is to confirm the operation of the high-voltage solar array which interacts with the ionospheric plasma. The interference was studied numerically and experimentally in the laboratory. In comparison to neutral particle drag, the ion forces were found to significantly affect spacecraft motion. With regard to the interaction of the 2D/HVSA in LEO, the drain power, ion force, and erosion of the solar cells were anticipated. K.K.

**AB9-38372**

**THE PHYSICS OF HIGH VOLTAGE POWER SYSTEMS IN CONTACT WITH THE SPACE ENVIRONMENT**

DANIEL E. HASTINGS (MIT, Cambridge, MA) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 2503-2508. refs  
Copyright

The physics of a positively biased conductor surrounded by dielectrics in contact with plasma is investigated. It is shown that due to the presence of secondary emission from the surrounding dielectrics the voltage of the surfaces near the conductor can be bistable. One of the bistable solutions always has very low secondary emission while the other has high secondary emission. The secondary current emitted from the neighboring dielectrics is collected by the conductor. When the voltage on the dielectric undergoes a transition from one bistable solution to another this will be seen as a concomitant increase in the current collected to the conductor. A theoretical treatment is presented for a conductor surrounded by dielectrics such as silicon dioxide. The theory is applied to explain the 'snapover' effect. The snapover effect is observed on high voltage solar arrays which involve the use of highly biased surfaces in contact with the space environment. It has been observed that when such surfaces are positively biased that the current undergoes an anomalous increase at a critical voltage. Author

## 17 SPACE ENVIRONMENT

AB9-38540

**THEORETICAL CONSIDERATIONS REGARDING SOME INELASTIC ATOMIC COLLISION PROCESSES OF INTEREST IN AERONOMY - DEACTIVATION AND CHARGE TRANSFER**  
DAVID R. BATES (Belfast, Queen's University, Northern Ireland)  
Planetary and Space Science (ISSN 0032-0633), vol. 37, March 1989, p. 363-368. refs  
(Contract AF-AFOSR-85-0202)  
(AD-A207306; AFGL-TR-89-0107) Copyright

Rate coefficients that have been adopted by aeronomers for some collision processes between neutral atoms and between neutral atoms and atomic ions are considered. As a partial check on them it is verified that they may be rationalized from published ab initio potential energy curves and straightforward application of the Landau-Zener approximation. Author

AB9-39071#

**THE EVALUATION OF SPACE RADIATION ENVIRONMENTS FOR ESA PROJECTS**  
E. J. DALY (ESA, Mathematics and Software Div., Noordwijk, Netherlands) ESA Journal (ISSN 0379-2285), vol. 12, no. 2, 1988, p. 229-247. refs  
Copyright

The natural space radiation environment and its effects on ESA projects are discussed, and methods and tools used by ESA for evaluating this environment and its effects are described. Various computer-based methods have been adopted, developed and applied to a variety of problems. Environment models are discussed, together with dose and upset-rate computation. Projects under consideration include astronomy and astrophysics missions, manned spacecraft and polar platforms. In the light of these activities, areas of concern requiring further attention are identified. Author

AB9-39153#

**SPACECRAFT INTERACTIONS AS INFLUENCED BY THERMOCHEMICAL CONSIDERATIONS**  
EDMOND MURAD (USAF, Geophysics Laboratory, Hanscom AFB, MA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 26, May-June 1989, p. 145-150. refs  
(AD-A211854)

Spacecraft in low earth orbit undergo harsh environmental interactions that sometimes resemble the phenomenon observed in high-temperature vaporization and oxidation. For example, it has been reported that an osmium surface is removed, and surfaces of aluminum, silver, copper, iridium, niobium, nickel, and tungsten, are oxidized, even though the surface temperature when the measurements are made is about 250 K. Similar results are observed for the case of nonmetallic samples, e.g., graphite and synthetic organic materials, which are removed quickly. The purpose of this paper is to examine the data from space experiments in light of thermochemical data and to consider possible implications or insight that may be gained for planning future experiments. Author

AB9-39361

**WHISTLER WINGS FROM MOVING ELECTRODES IN A MAGNETIZED LABORATORY PLASMA**  
R. L. STENZEL and J. M. URRUTIA (California, University, Los Angeles) Geophysical Research Letters (ISSN 0094-8276), vol. 16, May 1989, p. 361-364. refs  
(Contract NSF PHY-87-13829; NSF ATM-87-02793)  
Copyright

In a large laboratory plasma the current pattern set up by moving electrodes has been measured. It is observed that the current flows oblique to the magnetic field at an angle given by the electrode speed across the oblique flow and the current penetration along the oblique flow (which is controlled by whistler waves). The current pattern, characterized as 'whistler wings', occurs irrespective of whether the electrodes collect electrons/ions or emit fast electron beams. These results are relevant to active experiments in space involving electrodynamic tethers, beam injections, and large space stations. Author

**AB9-39395\*** Massachusetts Inst. of Tech., Cambridge.  
**THE PHYSICS OF POSITIVELY BIASED CONDUCTORS SURROUNDED BY DIELECTRICS IN CONTACT WITH A PLASMA**

DANIEL E. HASTINGS and PATRICK CHANG (MIT, Cambridge, MA) Physics of Fluids B (ISSN 0899-8221), vol. 1, May 1989, p. 1123-1132. refs  
(Contract AF-AFOSR-87-0340; NAG3-695)  
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The physics of a positively biased conductor surrounded by dielectrics in contact with plasma is investigated. It is shown that because of the presence of secondary emission from the surrounding dielectrics, the voltage of the surfaces near the conductor has three solutions. The high- and low-voltage solutions are stable, while the intermediate-voltage solution is unstable. This theory is applied to explain the snapover effect observed on high-voltage solar arrays that involve the use of highly biased surfaces in contact with the space environment. Author

AB9-39742

**SPACE DEBRIS**  
ELMAR VITT (Cologne Court of Appeals, Federal Republic of Germany) Space Policy (ISSN 0265-9646), vol. 5, May 1989, p. 129-137. refs  
Copyright

The basic facts about debris in outer space are reviewed and legal questions concerning the hazards of space debris are examined. The findings of the Cologne Colloquium on the protection of the space environment (Vitt, 1988) are discussed. A survey of proposals for protective measures is presented, including disposal orbits, the prevention of new debris production, and design changes to minimize debris. The application of the Outer Space Treaty of 1967, the Liability Convention of 1972, and other international laws to the problem of space debris is investigated. R.B.

**AB9-40114\*** National Aeronautics and Space Administration, Ames Research Center, Moffett Field, CA.

**POLYMER ETCHING IN THE OXYGEN AFTERGLOW - INCREASED ETCH RATES WITH INCREASED REACTOR LOADING**

N. R. LERNER and T. WYDEVEN (NASA, Ames Research Center, Moffett Field, CA) Electrochemical Society, Journal (ISSN 0013-4651), vol. 136, May 1989, p. 1426-1430. refs  
Copyright

Reactor loading has an effect on the etch rate (rate of decrease of film thickness) of films of polyvinylfluoride (Tedlar) and polyethylene exposed in the afterglow of an RF discharge in oxygen. The etch rate is found to increase with the total surface area of the polymer exposed in the reactor. The etch rates of polypyromellitimide (Kapton H) and polystyrene under these conditions are very low. However, the etch rate of these polymers is greatly enhanced by adding either Tedlar or polyethylene to the reactor. A kinetic model is proposed based on the premise that the oxygen atoms produced by the RF discharge react with Tedlar or polyethylene to produce a much more reactive species, which dominates the etching of the polymers studied. Author

**AB9-40188\*** Colorado State Univ., Fort Collins.

**GROUND-BASED TESTS OF HOLLOW CATHODE PLASMA CONTACTORS**

JOHN D. WILLIAMS and PAUL J. WILBUR (Colorado State University, Fort Collins) IN: International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989, Collection of Papers and Abstracts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 77-87. refs  
(Contract NAG3-776)  
(AIAA PAPER 89-1558) Copyright

Experimental results are presented which describe operation of and the plasma environment associated with a hollow cathode-based plasma contactor collecting electrons from an ambient, low density Maxwellian plasma when the boundary between the contactor and the ambient plasma is nearly

hemispherical. Basic physical features of the process of electron collection identified on the basis of these results include a double-sheath across which a substantial potential difference can develop and substantial ionization of neutral gas coming from the cathode by the electrons being collected. Experimental results obtained when the diameter of the anode is too small to yield a hemispherical double-sheath are shown to induce distortion of this sheath but it is argued that the same basic phenomena are still active in this case. Data obtained in these experiments should serve to validate numerical models of this process that are being developed to predict plasma contactor performance in space. Preliminary performance and plasma property results measured on a contactor emitting electrons are examined and some physical elements of this process are identified. *Author*

**A89-41039\*** Hughes Research Labs., Malibu, CA.  
**HIGH-CURRENT PLASMA CONTACTOR NEUTRALIZER SYSTEM**

J. R. BEATTIE, W. S. WILLIAMSON, J. N. MATOSSIAN, E. J. VOUGOURAKIS (Hughes Research Laboratories, Malibu, CA), J. L. BURCH (Southwest Research Institute, San Antonio, TX) et al. AIAA, NASA, Agenzia Spaziale Italiana, and ESA, International Conference on Tethers in Space - Toward Flight, 3rd, San Francisco, CA, May 17-19, 1989. 7 p. Research supported by the Southwest Research Institute and Hughes Aircraft Co. refs (Contract NAS8-32827) (AIAA PAPER 89-1603)

A plasma-contactor neutralizer system is described, for the stabilizing the Orbiter's potential during flights of the Atmospheric Laboratory for Applications and Science missions. The plasma contactor neutralizer will include a Xe plasma source that can provide steady-state ion-emission currents of up to 1.5 A. The Orbiter's potential will be maintained near that of the surrounding space plasma during electron-beam accelerator firings through a combination of ion emission from the Xe plasma source and electron collection from the ambient space plasma. Configuration diagrams and block diagrams are presented along with the performance characteristics of the system. *I.S.*

**A89-41707**  
**ELECTRIC FIELDS IN THE MAGNETOSPHERE - THE EVIDENCE FROM ISEE, GEOS, AND VIKING**

CARL-GUNNE FALTHAMMAR (Kungliga Tekniska Hogskolan, Stockholm, Sweden) IEEE Transactions on Plasma Science (ISSN 0093-3813), vol. 17, April 1989, p. 174-185. refs Copyright

Electric-field (EF) measurements on the satellites GEOS-1, GEOS-2, ISEE-1, and Viking have extended the empirical knowledge of EFs in space to include the outer regions of the magnetosphere. While the measurements confirm some of the theoretically expected properties of the EFs, they also reveal unexpected features and a high degree of complexity and variability. The existence of a magnetospheric dawn-to-dusk EF, as expected on the basis of extrapolation from low-altitude measurements, is confirmed in an average sense. However, the actual EF exhibits large spatial and temporal variations, including strong EFs of inductive origin. At the magnetopause, the average (dawn-to-dusk-directed) tangential EF component is typically obscured by irregular fluctuations of larger amplitude. In addition, data from EF measurements provide further support for the conclusion that a nonvanishing magnetic-field-aligned EF exists in the auroral acceleration region. *I.E.*

**A89-41711\*** Southwest Research Inst., San Antonio, TX.  
**SPACECRAFT CHARGING POTENTIAL DURING ELECTRON-BEAM INJECTIONS INTO SPACE PLASMAS**

CHIN S. LIN and JAMES KOGA (Southwest Research Institute, San Antonio, TX) IEEE Transactions on Plasma Science (ISSN 0093-3813), vol. 17, April 1989, p. 205-209. refs (Contract NAS8-32488; F19628-85-K-0004)

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Injections of nonrelativistic electron beams from an infinite conductor have been simulated by using a two-dimensional

electrostatic particle code to study the spacecraft charging potential. The simulations show that the conductor charging potential at the end of simulations does not vary with the beam density when the beam density exceeds four times the ambient density. The reflection coefficient, which determines a percentage of incident electrons reflected by the conductor, increases the charging potential. To charge the conductor to the beam energy, the reflection coefficient needs to be about 0.5. The results are applied to explain the spacecraft charging potential measured during the Sepac experiments on Spacelab 1. *I.E.*

**A89-43152**  
**ENCOUNTER SAFETY BETWEEN A GROUND LAUNCHED VEHICLE AND AN ORBITING VEHICLE**

JERRY BUKLEY (Riverside Research Institute, Huntsville, AL) IN: 1988 Annual Summer Computer Simulation Conference, 20th, Seattle, WA, July 25-28, 1988, Proceedings. San Diego, CA, Society for Computer Simulation International, 1988, p. 943-947. Copyright

The explosion of a booster engine can produce a large cloud of high energy particles capable of damaging an orbiting observer. A method is outlined in this report which describes how to determine from any location relative to the observer whether an explosion is capable of sending particles within its vicinity. The trajectories of individual particles are ballistic after an explosion; thus, their relative motion can be described as a function of velocity necessary to generate an encounter. This velocity is optimized to determine the minimum velocity to intersect with the orbiting platform. The minimum velocities are used to generate 'isosped' lines which describe the intersecting velocity field. *Author*

**A89-43271\***  
**EFFECTS OF NATURAL ENVIRONMENT CHARGED PARTICLE HEATING ON THE DESIGN AND PERFORMANCE OF SPACECRAFT CRYOGENIC COMPONENTS**

R. D. JIMENEZ (Orion International Technologies, Inc., Albuquerque, NM) AIAA, Thermophysics Conference, 24th, Buffalo, NY, June 12-14, 1989. 7 p. Research supported by USAF. refs (AIAA PAPER 89-1760) Copyright

This paper examines the heating effects of the near-earth natural environment trapped charged particles on the design and performance of space-borne cryogenic (less than 100 K) components. The results demonstrate that the charged particle heating source must be carefully considered during the design of a spacecraft thermal management subsystem. Applications of the results include the mass penalty of a simplified spacecraft cryogenic radiator designed to manage the additional heating of the trapped charged particles. *Author*

**A89-43272\***  
**ATOMIC OXYGEN EFFECT ON PHYSICAL PROPERTIES OF SPACECRAFT MATERIALS IN LOW EARTH ORBIT**

KATSUMI SONODA, TAKAO NISHIKAWA, and KOUICHIROU NAKANISHI (Mitsubishi Electric Corp., Manufacturing Development Laboratory, Amagasaki, Japan) AIAA, Thermophysics Conference, 24th, Buffalo, NY, June 12-14, 1989. 6 p. refs (AIAA PAPER 89-1761) Copyright

The degradation behavior of spacecraft materials in low earth orbit due to atomic oxygen was examined under the exposure of oxygen plasma, as the ground based test. The oxygen plasma by rf discharge was diagnosed in-situ by an optical spectrometer and a mass spectrometer. Their degradations were estimated quantitatively by thickness loss. It is observed that the degradation test which simulates actual flight (STS-5) should be performed in the low rf power region, in which atomic oxygen appeared to be dominant. After the irradiation, the surface analysis of the samples were performed by ESCA. Based on these analyses, the degradation mechanisms of irradiated samples are discussed in this paper. *Author*



A89-43352

**MODEL OF THE INTERACTION OF A HOLLOW CATHODE WITH THE IONOSPHERE**

M. DOBROWOLNY and L. IESS (CNR, Istituto di Fisica dello Spazio Interplanetario, Frascati, Italy) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 206-210. refs  
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Self-consistent calculations of the expansion of a plasma source of the hollow cathode type into an ambient plasma are presented. The source is polarized with respect to the surrounding medium. The model considered is a fluid model with inclusion of anomalous friction arising from plasma instabilities. The potential profiles which are calculated show a very large extent of the interaction region. Correspondingly quite substantial current enhancements with respect to the operation of the plasma source in vacuum are obtained. Author

**A89-43356\*** Systems Science and Software, San Diego, CA.  
**ON THE NEED FOR SPACE TESTS OF PLASMA CONTACTORS AS ELECTRON COLLECTORS**

IRA KATZ and VICTORIA ANN DAVIS (Systems Science and Software, San Diego, CA) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 241-244. refs  
(Contract NAS3-23881)  
Copyright

An analysis is presented of laboratory experiments that have shown that hollow plasma sources can provide low-impedance contact with a background plasma. In particular, some experiments show an report an 'ignited mode' of electron collection using plasma sources where almost an ampere was collected at a potential of 100 volts. The experimental results are compared with theoretical and computational models of plasma layers. Preliminary results indicate that the measured potential profiles and collected currents during the 'ignited mode' correspond to an increase in the background plasma thermal current of more than an order of magnitude. The results imply that the 'ignited mode' results are substantially impacted by the laboratory electron source and the tank size. Only experiments performed in space will be able to provide the correct boundary conditions for reliably testing high electron collection by plasma contactors. C.D.

**A89-43358\*** Consiglio Nazionale delle Ricerche, Frascati (Italy).  
**EXPERIMENTAL CHARACTERIZATION OF**

**HOLLOW-CATHODE PLASMA SOURCES AT FRASCATI**

G. VANNARONI, C. B. COSMOVICI, C. BONIFAZI (CNR, Istituto di Fisica dello Spazio Interplanetario, Frascati, Italy), and J. MCCOY (NASA, Johnson Space Center, Houston, TX) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 254-260. Research supported by CNR. refs  
Copyright

An experimental characterization has been conducted for hollow cathodes applicable as plasma contactors on Space Shuttle-based experiments. The diagnostics tests were conducted in an 0.5 cu m vacuum chamber by means of Langmuir probes at various distances from the source. Two electron populations are noted, one in the 0.3-1 eV and the other in the 7-11 eV temperature range. Current developments in the design of plasma chambers incorporating magnetic field compensation are noted. O.C.

**A89-43359\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, OH.

**GROUND-BASED PLASMA CONTACTOR CHARACTERIZATION**

MICHAEL J. PATTERSON (NASA, Lewis Research Center, Cleveland, OH) and RANDALL S. AADLAND IN: Space tethers for science in the space station era; Proceedings of the Second

International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 261-268. refs  
Copyright

This paper presents recent NASA Lewis Research Center plasma contactor experimental results, as well as a description of the plasma contactor test facility. The operation of a 24-cm-diameter plasma source with hollow cathode was investigated in the 'ignited-mode' regime of electron current collection from 0.1 to 7.0 A. These results are compared to those obtained with a 12-cm plasma source. Full two-dimensional plasma potential profiles were constructed from emissive probe traces of the contactor plume. The experimentally measured dimensions of the plume sheaths were then compared to those theoretically predicted, using a model of a spherical double sheath. Results are consistent for currents up to approximately 1.0 A. For currents above 1.0 A, substantial deviations from theory occur. These deviations are due to sheath asphericity, and, possibly, volume ionization in the double-sheath region. Author

**A89-43361\*** Science Applications International Corp., McLean, VA.

**FUNDAMENTAL PRINCIPLES OF  
HOLLOW-CATHODE-DISCHARGE OPERATIONS IN SPACE  
AND THE DESIGN OF A ROCKET-BORNE DEMONSTRATION**

EDWARD P. SZUSZCZEWICZ (Science Applications International Corp., McLean, VA), JAMES E. MCCOY (NASA, Johnson Space Center, Houston, TX), CARLO BONIFAZI, and MARINO DOBROWOLNY (CNR, Istituto di Fisica dello Spazio Interplanetario, Frascati, Italy) IN: Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987. Bologna, Societa Italiana di Fisica, 1988, p. 279-285. refs  
Copyright

The issue of hollow-cathode operations in space is treated from the point of view of fundamental principles of plasma interactions and their control over currents involving the device, the spaceborne vehicle, and the ambient space plasma. Particular attention is given to collective plasma processes, the effects of the ambient magnetic field, and the high probability of plasma turbulence triggered by hollow cathode operations. The paper presents a rocket payload and experiment scenario designed for accommodation on a Black Brant booster, launched from a midlatitude site to an apogee in excess of 400 km. K.K.

A89-43365

**SPACE DEBRIS - ORIGIN, EVOLUTION AND COLLISION MECHANICS**

D. REX, P. EICHLER, U. SOPPA, J. ZUSCHLAG, and A. BADE (Braunschweig, Technische Universität, Brunswick, Federal Republic of Germany) (IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988) Acta Astronautica (ISSN 0094-5765), vol. 20, 1989, p. 209-216. Research supported by BMFT.  
Copyright

The number of man-made objects orbiting the earth and the corresponding collision risk has become a concern, which deserves thorough investigation. In addition to the 3500 objects launched and presently still in orbit, about 10 to 20 times as many debris particles down to 1 cm in size have been produced in earth orbits by unintentional and intentional break-ups. The number and orbital data of the majority of these smaller debris particles cannot be determined by tracking. So a complete mathematical analysis of nearly all 90 reported break-ups has been performed, generating the numbers of fragments, their mass- and mass/area-distribution and their orbits. This simulation also includes the variation of all orbits with time, especially the descent and removal of objects by atmospheric drag and lunisolar perturbations. On the basis of this data, bank scenarios for the future development of space debris and collision probabilities are derived, showing that the highest accumulation of debris presently at an altitude of 800-1000 km, will shift to 1400 km on the long term. Collision risk and geometry is determined by a deterministic model which can also be used to design shielding. Author

## ABR-44049#

## SPACELAB D1 OFFGASSING EXPERIMENT (SOGS)

M. D. JUDO, J. A. QUEMENER (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands), and H. SCHUERMANN (DLR, Cologne, Federal Republic of Germany) *ESA Journal* (ISSN 0379-2285), vol. 13, no. 1, 1989, p. 19-25.

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Gaseous contaminants in the cabin atmosphere of Spacelab D1 were collected using adsorption traps and were quantitatively identified with combined gas chromatography and mass spectrometry. The equipment used to collect the samples is described, including the nine adsorption sampling traps. Results are presented from analysis of the samples, showing that certain contaminants are present at relatively high concentrations which vary markedly with time. It is suggested that these contaminants are associated with medical experiments on Spacelab. Contaminants generated by the flight hardware were present at very low levels. R.B.

## ABR-44485

## IMPACTS OF LARGE DUST PARTICLES ON THE VEGA SPACECRAFT

H. LAAKSO, R. GRARD, A. PEDERSEN, and G. SCHWEHM (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) (COSPAR, IAGA, and IAU, Plenary Meeting, 27th, Symposium, Workshop, and Topical Meeting on Cometary Environments, Espoo, Finland, July 18-29, 1988) *Advances in Space Research* (ISSN 0273-1177), vol. 9, no. 3, 1989, p. 269-272. refs

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The two Vega spacecraft carried electric field and Langmuir probes on booms extending from the outer edges of the solar panels. Impulsive signal increases were observed simultaneously with all sensors and occurred more frequently toward closest approach. These events have been interpreted as impacts of dust particles on the spacecraft, which acted as a large dust collector, with a cross-section area of about 10 sq m perpendicular to the ram direction. These results are discussed on the background of other Vega dust measurements. Author

## ABR-44802

## PLASMA-JET CONVERSION OF HIGH-POWER MICROWAVE RADIATION AND POWER SUPPLY TO SPACE STATION [PLAZMENNO-FAKEL'NOE PREOBRAZOVANIE MOZHCHNOGO SVCH IZLUCHENIIA I ENERGOPITANIE KOSMICHESKIKH STANTSII]

G. A. ASKARIAN, G. M. BATANOV, and I. A. KOSSYI (AN SSSR, Institut Obshchei Fiziki, Moscow, USSR) *Pis'ma v Zhurnal Tekhnicheskoi Fiziki* (ISSN 0320-0116), vol. 15, April 26, 1989, p. 18-23. In Russian. refs

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The possibility of using plasma-jet conversion for microwave energy transmission to space vehicles is examined with reference to specific examples. It is shown that the use of compact plasma converters operating at high power levels significantly simplifies energy transmission to space vehicles. Schemes using satellites moving at heights of 100-1000 km may be more practical than stations in geostationary orbits at 36,000 km, since large distances require large receive areas. V.L.

## ABR-45265\*# Johns Hopkins Univ., Laurel, MD.

## THE ABUNDANCES OF ELEMENTS AND ISOTOPES IN THE SOLAR WIND

GEORGE GLOECKLER (Johns Hopkins University, Laurel, MD) and JOHANNES GEISS (Bern, Universitaet, Switzerland) *AIP, Symposium on Cosmic Abundances of Matter, Minneapolis, MN, Aug. 15-17, 1988, Paper. 24 p.* Research supported by NSF. refs

(Contract NAGW-101; NAG5-716; N00039-87-C-5301)

Studies of the chemical and isotopic composition of the solar wind are reviewed. Solar wind abundance measurements are discussed and solar wind, coronal, and photospheric abundances for elements between H and Fe are presented. Also, consideration

is given to the determination of the solar wind isotopic composition of the noble gases using foil collection techniques and the observation of solar wind heavy ions with the mass per charge spectrometer on ISEE-3. Other topics include solar wind observations with solid state detectors, solar wind abundances in the magnetosheath and the plasma sheet, and high-mass resolution measurements of chemical elements and isotopes in the solar wind. R.B.

## ABR-45630

## HIGH-VOLTAGE POLAR-ORBIT AND BEAM-INDUCED CHARGING OF A DIELECTRIC SPACECRAFT - A WAKE-INDUCED BARRIER EFFECT MECHANISM

J. G. LAFFRAMBOISE and J. LUO (York University, Downsview, Canada) *Journal of Geophysical Research* (ISSN 0148-0227), vol. 94, July 1, 1989, p. 9033-9048. refs

(Contract F19628-83-K-0029; NSERC-A-4638)

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A mechanism is proposed which permits high-voltage auroral zone charging to occur on a large dielectric spacecraft, in situations where such charging would be expected to be suppressed due to secondary-electron or photoelectron escape from exposed surfaces. The proposed mechanism involves the suppression of electron emission by a potential barrier in the spacecraft wake, produced by unbalanced electron space charge. In contrast to barrier effect charging in GEO conditions, this potential barrier produces differential charging, instead of limiting it; instead of a saddle point, the potential distribution involves a minimum which migrates toward the spacecraft and almost reaches it as the spacecraft charges toward a steady state. This mechanism is applied to explain some features of the Shuttle Orbiter charging observed during the SEPAC (Space Experiments with Particle Accelerators) Spacelab 1 electron beam experiment. I.S.

## ABR-45631\* Utah State Univ., Logan.

## A NUMERICAL MODEL OF ELECTRODYNAMICS OF PLASMA WITHIN THE CONTAMINANT GAS CLOUD OF THE SPACE SHUTTLE ORBITER AT LOW EARTH ORBIT

J. VINCENT ECCLES, W. JOHN RAITT (Utah State University, Logan), and PETER M. BANKS (Stanford University, CA) *Journal of Geophysical Research* (ISSN 0148-0227), vol. 94, July 1, 1989, p. 9049-9063. refs

(Contract NAG3-792; NAGW-235)

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A two-dimensional cloud was used to study the plasma dynamics within the outgas cloud associated with the Orbiter. It is shown that the polarization field is not symmetric about the direction of motion of the outgas cloud. It rotates in a way that can be predicted in simple cases by the ratio of the Hall and Pederson currents within the outgas cloud. The polarization field magnitude produced in the model was not large. K.K.

## ABR-45632\* Jet Propulsion Lab., California Inst. of Tech., Pasadena.

## THE POLAR CODE WAKE MODEL - COMPARISON WITH IN SITU OBSERVATIONS

G. MURPHY (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) and I. KATZ (Systems Science and Software, La Jolla, CA) *Journal of Geophysical Research* (ISSN 0148-0227), vol. 94, July 1, 1989, p. 9065-9070. refs

(Contract NAS8-32807; F19628-86-C-0056; NAG3-449)

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Measurements made by the plasma diagnostics package during Spacelab 2 are discussed and compared with predictions made with the Air Force Geophysics Laboratory POLAR wake code. This code uses a complex geometric model of the orbiter and the self-similar solution of the expansion of a plasma into a vacuum as its model basis. Excellent qualitative and quantitative agreement is found at distances greater than about 30 m. At least to the first order, the model's approximations are justified. K.K.

## 17 SPACE ENVIRONMENT

**ABN-45640\*** Princeton Univ., NJ.

### **A SURFACE CHEMISTRY MODEL FOR THE ALTITUDE DEPENDENCE OF THE N<sub>2</sub> LYMAN-BIRGE-HOPFIELD GLOW ON SPACECRAFT**

J. W. CUTHBERTSON and W. D. LANGER (Princeton University, NJ) *Journal of Geophysical Research* (ISSN 0148-0227), vol. 94, July 1, 1989, p. 9149-9154. refs  
(Contract NASA ORDER H-83097-B)  
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Low-orbiting spacecraft have been observed to cause UV emission in the N<sub>2</sub> Lyman-Birge-Hopfield bands. The chemical processes expected to underlie this emission are examined. Recombination between incident and adsorbed N atoms has been proposed as the source of radiating excited N<sub>2</sub>. However, the cubic dependence of the intensity, as N<sub>2</sub> concentration cubed or N<sub>2</sub> concentration squared x O concentration, has not been explained. It is suggested that this can be explained by a model where adsorption of nitrogen on the spacecraft surface is balanced mainly by the removal of N from the surface by atomic oxygen. On the basis of these assumptions a mathematical model for the production of excited N<sub>2</sub> is constructed. It is shown that for large enough reaction efficiencies the model predicts a magnitude and altitude dependence for the emission which can explain the measurements reported by other investigators. Author

**ABN-45749**

### **EXTRATERRESTRIAL APPLICATION OF SOLAR OPTICS FOR INTERIOR ILLUMINATION**

DAVID A. ELIADI and KYLE D. WILLIAMS (BRW, Inc., Minneapolis, MN) *IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 296-309. refs*  
Copyright

Two beamed sunlight systems are discussed: passive solar optics (PSO) and active solar optics (ASO). ASO and PSO are systems for transmitting sunlight to remote interior spaces; ASO is most appropriate for task illumination, while PSO is most appropriate for general illumination. Particular attention is given to the prism light guide, a solar optic component which has been identified as having potential for use in the Space Station CELSS modules and on lunar bases. A first attempt to identify potential uses of solar optic technology for interior illumination of several lunar base concepts is presented. B.J.

**ABN-45773**

### **RADIATION HAZARDS TO SPACE CONSTRUCTION - THE ENERGETIC PARTICLE ENVIRONMENT**

MICHAEL F. STANFORD and JEFFREY S. SCHLEHER (BDM Corp., Albuquerque, NM) *IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 584-595. refs*  
Copyright

The paper presents a description of space 'climatology' to provide a basis for evaluating the risk associated with space construction from the energetic particle environment. It has been found that the degree of hazard posed by the energetic particle environment varies with the orbit considered and with the 11-year solar cycle. The primary sources of this environment are the earth's radiation belts, cosmic rays, and solar events. It is suggested that, at the proposed altitude and inclination of the Space Station, these hazards can be minimized by planning. Planning factors include the forecasts of solar proton events and geomagnetic storms and the reduction of EVA in the South Atlantic Anomaly region. B.J.

**ABN-45775**

### **DIFFERENTIAL GRAVITATIONAL FORCES ON LARGE SPACE STRUCTURES**

R. B. MALLA (Connecticut University, Storrs), W. A. NASH, and T. J. LARDNER (Massachusetts University, Amherst) *IN: Engineering, construction, and operations in space; Proceedings*

*of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 620-631. refs*

(Contract AF-AFOSR-83-0025)

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Effects of the differential gravitational forces have been investigated simultaneously on the orbital motion, attitude motion, and axial deformation of a very large axially flexible space structure executing planar pitch motion. Also, included in the present study are the effects of total mass of the space system and attractive forces among concentrated masses present in the structure. It is observed that these parameters do not have appreciable effects on the structure's orbital motion, attitude motion, and axial length (deformation). Author

**ABN-45812**

### **NON-IONIZING RADIATION EXPOSURE IN SPACE ACTIVITIES**

ARTHUR E. SCHULZE (Lovelace Scientific Resources, Webster, TX) *IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 1056-1063. refs*

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Approaches to limit human exposure to nonionizing RF radiation during EVA are examined. Adverse health effects of exposure to RF radiation are listed and the potential exposure sources in space are discussed. Actions that may be taken to reduce the health risks of RF radiation exposure are outlined. It is suggested that terrestrial exposure limits should be evaluated for application to the space environment. R.B.

**ABN-45824**

### **NATURE'S SOLUTIONS TO SPACE INSULATION**

SCOTT CARY, MIKE KIRCHOFF, and MIKE PLATT *IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 1186-1196. refs*

Copyright

The adaptation of natural plant and animal insulation methods for space applications is discussed. The possible applications of a vacuum as an insulator and foam as a substitute for natural insulation are examined, focusing on insulation using foam distributed within a vacuum. The curing ability of solid polyurethane foam is tested experimentally at different pressures. It is suggested that a foam which can cure in a vacuum should be developed for using in spray on foam insulation panels. R.B.

**ABN-46715#**

### **INTERACTION BETWEEN A PLASMA FLOW AND A HIGHLY BIASED SOLAR ARRAY**

DANIEL E. HASTINGS, MENGU CHO, and PATRICK CHANG (MIT, Cambridge, MA) *AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 12 p. refs*  
(Contract AF-AFOSR-87-0340)  
(AIAA PAPER 89-2272) Copyright

Magnetic forces have been incorporated into a two-dimensional particle-in-cell simulation of current collection in a solar cell interconnector in order to investigate the influence of magnetic fields on snapover, the anomalous increase in current collection found in highly biased solar arrays. Snapover is regulated by the ability of secondary electrons to escape the dielectric coverglasses and exit through the conductor, and the presence of a magnetic field is shown to inhibit this escape and increase the voltage required for snapover. Drag calculations are performed which take into account the effect of having the conductor surrounded by dielectrics, as well as the charging of the dielectric by electrons. R.R.

**ABN-47439#**

### **INTERACTION OF HIGH VOLTAGE SOLAR ARRAY WITH IONOSPHERIC PLASMA**

H. KUNINAKA, K. KURIKI (Institute of Space and Astronautical



Science, Sagami, Japan), S. SATORU, and Y. NOZAKI IN: International Electric Propulsion Conference, 20th, Garmisch-Partenkirchen, Federal Republic of Germany, Oct. 3-6, 1988, Proceedings, Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1988, p. 105-114. refs

A numerical and experimental study of interference phenomena occurring on the High Voltage Solar Array due to the ionospheric plasma is presented. The numerical model takes into account the drain power, the ion force, and the erosion of the solar cells. Experimentally obtained macroscopic data (such as the total ion current and the ion drag and lift) and data for the distributions of the space potential and the ion current density are found to agree well with the numerical results. In addition to the well-known interference effects, the study has led to the discovery of such new phenomena as the influence of ion drag on the spacecraft motion and the surface degradation by sputtering. R.R.

ABR-48068

THE CAPACITANCE OF A SATELLITE MOVING IN THE IONOSPHERE AND THE TIME OF THE ESTABLISHMENT OF ITS POTENTIAL WITH TEMPERATURE VARIATION OF THE AMBIENT PLASMA [EMKOST' SPUTNIKA, DVIZHUSHCHEGOSIA V IONOSFERE, I VREMIA USTANOVLENIIA EGO POTENTIALA PRI IZMENENII TEMPERATURY OKRUZHAIUSHCHEI PLAZMY]

S. A. GORBUNOV, T. L. POTAPOVA, and A. E. REZNIKOV Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 27, May-June 1989, p. 407-410. In Russian. refs

Copyright

The capacitance of a body moving in the ionosphere is calculated assuming that its size is large compared with the plasma Debye radius, and that the frequency of the potential change on the surface is much lower than the electron plasma frequency. The establishment of potential on the surface of a satellite with temperature variation of the ambient plasma is investigated, and the time of potential establishment determined by the satellite capacitance is calculated. It is shown that this time is much less than that of the establishment of the electron distribution in the boundary layer. B.J.

ABR-48147

IN-SITU STUDIES OF COSMIC DUST AND PRIMORDIAL BODIES - THE PLAN AHEAD

J. A. M. McDONNELL, T. J. STEVENSON, S. M. TULLOCH, and S. F. GREEN (Kent, University, Canterbury, England) British Interplanetary Society, Journal (ISSN 0007-084X), vol. 42, July 1989, p. 315-322.

Copyright

Multinational projects undertaken for the study of cosmic dust and primordial bodies are described. Consideration is given to the Long Duration Exposure Facility, the Timeband Capture Cell Experiment, and the Space Station Freedom facilities. Also discussed are the Mir space station, Ulysses, Cassini, the Comet Rendezvous and Asteroid Flyby mission, and Rosetta. K.K.

ABR-48670#

SPACE DEBRIS AND MILITARY TESTING

CARL Q. CHRISTOL IN: Colloquium on the Law of Outer Space, 31st, Bangalore, India, Oct. 13, 14, 1988, Proceedings, Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 234-242. refs

Copyright

The issue of whether the testing of antisatellite satellites (ASATs) in outer space creates conditions hazardous to peaceful and beneficial activities is addressed. ASAT characteristics and capabilities are analyzed. The relationship between ASAT testing and the testing of other space weapons is identified. The policy reasons for testing are explored. Finally, an assessment is made of the role of international space law in dealing with military activities in space. Author

ABR-50526\* National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, TX.

DETERMINATION OF THE AREA AND MASS DISTRIBUTION OF ORBITAL DEBRIS FRAGMENTS

GAUTAM D. BADHWAR (NASA, Johnson Space Center, Houston, TX) and PHILLIP D. ANZ-MEADOR (Lockheed Engineering and Sciences Co., Houston, TX) Earth, Moon, and Planets (ISSN 0167-9295), vol. 45, April 1989, p. 29-51. refs

Copyright

A technique is described to estimate the area-to-mass ratio of debris fragments using orbital fragments obtained by radar. The area-to-mass ratio of about 2600 fragments arising from the breakup of 24 artificial satellites was determined; an analysis of the data on about 200 objects with known mass, size, and shape has been made, and a calibration of the observed radar cross-section (RCS) to the effective area of these objects has provided a method to estimate the effective area of debris fragments. From the knowledge of the effective area and the estimated area-to-mass ratio, the mass and area distribution of each of the known breakup has been obtained. As a function of time, the orbital elements can be used to invert any propagation algorithm to yield the area-to-mass ratio of an orbiting object. C.E.

ABR-50527

A MODEL OF THE TERRESTRIAL IONOSPHERE IN THE ALTITUDE INTERVAL 50-4000 KM. I - ATOMIC IONS (H+, HE+, N+, O+)

W. KOEHNLEIN (DLR, Weßling; Bonn, Universitaet, Federal Republic of Germany) Earth, Moon, and Planets (ISSN 0167-9295), vol. 45, April 1989, p. 53-100. Research supported by DFG. refs

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An empirical model of atomic ion densities (H+, He+, N+, O+) is presented up to 4000 km altitude as a function of time (diurnal, annual), space (position, altitude), and solar flux (F10.7) using observations of satellites (AE-B, AE-C, AE-D, AE-E, ISIS-2, OGO-6) and rockets during quiet geophysical conditions (Kp less than or equal to 3). The numerical treatment is based upon harmonic functions for the horizontal pattern and cubic spline for the vertical structure. Around polar regions, the light ions H(+) and He(+) are depleted by the polar wind and enhanced. During local summer conditions the ion densities increase around polar latitudes and decrease during local winter, except He(+) which reflects the opposite pattern. The atomic ions N(+) and O(+) reach a peak during daytime. C.E.

ABR-50745

NON-IONIZING ELECTROMAGNETIC ENVIRONMENTS ON MANNED SPACEFLIGHT

J. R. MURPHY British Interplanetary Society, Journal (ISSN 0007-084X), vol. 42, Aug. 1989, p. 383-390. refs

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The exposure limits and biological effects of nonionizing EMFs during spaceflight are discussed. The relationship between the geomagnetic field and human behavior is considered. Estimates are given of the suggested limits for exposure to static electric and magnetic fields, LF EMFs, LF magnetic fields, RF EMFs, microwave EMFs, and light-frequency EMFs. The importance of considering electromagnetic environments in spacecraft design is noted. R.B.

ABR-51110\* National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

SPACE RADIATION EFFECTS ON DIMENSIONAL STABILITY OF COMPOSITES

DARREL R. TENNEY and DAVID E. BOWLES (NASA, Langley Research Center, Hampton, VA) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 133-144. refs

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The long-term space environment at GEO, consisting of high doses (less than 10 to the 9th rads) of electron radiation and

large cyclic (-157 C to +121 C) temperature changes, can significantly affect the dimensional stability of polymer matrix composites. Radiation alters the chemical structure of epoxies by both chain scission and cross-linking. In this paper, an attempt is made to summarize and examine the effects of electron radiation damage on dimensional stability of composites. Microcracking measurements were made for standard 177 C cure Gr/Ep, rubber toughened Gr/Ep, Gr/Polymide, and GR/Thermoplastic composites. Results show that radiation damage can significantly change matrix-dependent mechanical and physical properties of composites, with data explaining how these changes can affect their dimensional stability. C.E.

#### ABR-51114

##### THE EFFECT OF LEO RADIATION ON COLUMBUS VIEWPORT GLASSES PANES

M. C. KENNEDY (Atomic Energy Research Establishment, Harwell, England) and P. L. MUELLER-REMMERS (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 183-199. Research supported by ESA. refs

Laminated soda-lime glass samples consisting of two pieces separated by a PVB layer have been irradiated with electrons, protons, Co-60 gamma-rays and X-rays. The glasses visibly darkened after receiving doses comparable to those expected from ten years in orbit. Analysis of the absorption spectra showed this darkening was due to a strong absorption band centered at 420 nm and a weaker band centered at 625 nm common to all types of radiation studied. The least amount of darkening was found for proton irradiation. Electrons at 400 keV gave a greater degree of darkening as their range is approximately ten times longer. No changes were found in the near infrared absorption or infrared reflectance spectra recorded before and after irradiation with any type of radiation. Scanning Electron Microscopy was also used to investigate small specimens of the glass used in viewports, these studies did not show any changes due to irradiation. C.E.

#### ABR-51116

##### PARTIAL DISCHARGE PHENOMENA IN SPACE APPLICATIONS

A. R. FREDERICKSON (USAF, Geophysics Laboratory, Hanscom AFB, MA) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 221-231. refs

Irradiation of good insulators by energetic charged particles in the natural space environment produces a number of spacecraft failure mechanisms. Electric fields in irradiated insulators cause plasma streamer discharge events. These events can be partial discharges, or they can lead to full breakdown of the insulator. The boundary conditions on the electric fields determine whether the pulses are large or small. This paper reviews the physics of partial electrical discharges and identifies several of the failure mechanisms. Author

#### ABR-51117

##### TRIPLE-ROOT JUMP IN SPACECRAFT CHARGING - THEORY AND OBSERVATION

S. T. LAI (USAF, Geophysics Laboratory, Hanscom AFB, MA) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 251-258. refs (AD-A210398; AFGL-TR-89-0162) Copyright

Sudden onsets of high-voltage differential charging are hazardous to the health of on-board spacecraft electronics. A triple-root jump (TRJ) in spacecraft charging may cause such sudden onsets. It is important to understand under what space conditions TRJ's would occur. By means of a double Maxwellian current balance model, parametric maps which delineate TRJ

domains have been obtained, revealing the relationship between these parametric domains and the 'threshold' temperature for spacecraft charging. Evidence of a plausibly observed TRJ is presented by analyzing data obtained on the SCATHA satellite. Some heretofore unsuspected spacecraft situations under which TRJ's may occur are discussed. Author

#### ABR-51118

##### CALCULATION OF ENVIRONMENTAL EFFECTS ON SPACECRAFT SURFACE USING MONTE-CARLO TECHNIQUE APPLICATION TO CONTAMINATION AND ATOMIC OXYGEN

CHARLES KOECK and MICHEL FREZET (Matra Defense et Espace, Toulouse, France) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 263-273. refs

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The interaction between the environmental medium and a spacecraft in orbit presents several aspects - air drag, radiation pressure, atomic oxygen, contamination - which must be properly predicted, in order to insure a correct functioning of the vehicle all along its mission life. Owing to the important role played by the geometrical configuration of the spacecraft, ray-tracing techniques combined with stochastic methods are found to be very appropriate to the numerical simulation of those phenomena. This paper presents the application of this technique to the prediction of atomic oxygen effects, micrometeorites impacts and outgassing contamination. Author

#### ABR-51119

##### SPACECRAFT CONTAMINATION CONTROL AND THE SELECTION OF MATERIALS

E. N. BORSON (Aerospace Corp., Materials Sciences Laboratory, Los Angeles, CA) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 275-283. refs

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In order to meet the cleanliness requirements of existing and proposed complex and long life space systems, contamination control must be a systems engineering function that begins at design conception. The systems approach requires a contamination control plan for each project and a generic methodology to determine if the procedures are effective with respect to performance and cost. The selection of materials is an integral and important part of this process. Analytical models and codes are used to estimate molecular contamination. Outgassing ASTM-tests are performed on components and subsystems (actual or simulated) under the expected flight environments. Pre-launch control of sources of molecular contaminants within facilities used to manufacture, assemble, and test spacecraft is considered to be an important criterion as well. Standard specifications and procedures are used to simplify the procurement and manufacturing processes to improve quality control. C.E.

#### ABR-51120

##### THE EFFECTS OF BI-PROPELLANT THRUSTER CONTAMINANTS ON SPACECRAFT MATERIALS

H. TRINKS (Hamburg, Technische Universität, Federal Republic of Germany) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 285-295. Research sponsored by ESA. refs

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Bi-propellant thrusters will be extensively used in the future for spacecraft orbit attitude control functions. The satellite design community is concerned with plume contamination effects outgoing from these thrusters on spacecraft sensitive surfaces. In the HAMBURG aerospace high vacuum test facility real bi-propellant thrusters in the thrust range between 5 and 60 Newton were investigated in connection with the contamination effects on solar cells, optical sensors, thermal control surfaces and satellites

surface materials. A surface contamination data base will be realized under sponsorship of ESA. Author

#### AB9-51121

##### APPLICATION OF LASER SIMULATION OF HYPERVELOCITY IMPACTS TO SPACE PARTICULATE DAMAGE TO METALS AND OPTICAL GLASSES

D. C. HILL, T. J. STEVENSON, and J. C. ZARNECKI (Kent, University, Canterbury, England) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 297-307. Research sponsored by Auburn University and University of Kent. refs  
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Simulation of hypervelocity micrometeoroid impacts in optical glasses, in particular, solar cell cover slides, using both KrF excimers and Nd:YAG lasers, is reported. Experimental results emphasize the correct crater morphology, including evidence of a central hydrodynamic flow region and fracture zones, for optical glasses. Additionally, applications of this simulation technique are outlined for the study of the operation of electrically-active spacecraft subsystems (e.g., solar arrays) and optical subsystems when exposed to the near-earth orbital debris environment. Emphasis is placed on the extension of this technique, by varying laser radiation wavelength to maximize surface absorption, to new and advanced materials for space use. An innovative technique for ejecta distribution studies is also reported in the context of assessing the contribution of ejecta to the orbital debris environment. Author

#### AB9-51122

##### TECHNOLOGY AND DESIGN FOR COLUMBUS DUE TO METEOROID/DEBRIS IMPACT

SALVATORE FALCONE (Aeritalia S.p.A., Turin, Italy) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 309-366. refs  
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The two Columbus elements, Pressurized Module (PM) and Man-Tended Free Flyer (MTFF) are expected to be struck by objects larger than those that hit previous manned spacecraft because of their larger size and longer time on orbit. The damage that these objects will cause are evaluated by performing a dedicated technological study, the so-called Meteoroid/Debris Protection shield (MOPS) study which is being conducted by the Aeritalia Space Systems Group, under ESA/ESTEC contract, and with the participation of MBB/ERNO, Ernest Mach Institut, and Engineering System International. The present paper describes the criteria on which the study was based and the main results achieved during the experimental and theoretical activities showing the damage to the protection shields when impacted at hypervelocity. Equations and evaluations versus the test results are presented. Author

AB9-51123\* National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

##### LOW EARTH ORBITAL ATOMIC OXYGEN SIMULATION FOR MATERIALS DURABILITY EVALUATION

BRUCE A. BANKS and SHARON K. RUTLEDGE (NASA, Lewis Research Center, Cleveland, OH) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 371-382. refs  
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The erosion yields of numerous materials have been evaluated in low earth orbital space tests. There appears to be three classes of materials: materials of high erosion yield which include most of the hydrocarbon organic materials; materials which either do not react with atomic oxygen or form self-protecting oxides which allow the underlying material to appear durable to atomic oxygen, and materials with low but nonnegligible erosion yields, such as fluoropolymers. A NASA atomic oxygen effects test program has been established to utilize collective data from a multitude of

simulation facilities to promote an understanding of mechanism and erosion yield dependencies. Atomic oxygen protective coatings for Kapton polyimide solar array blankets, fiberglass-epoxy composite mast structures, and solar dynamic power system concentrator surfaces have been identified and evaluated under atomic oxygen exposure in RF plasma after laboratory tests. The control of defect density in protective coatings appears to be the key to the assurance of long-term protection of oxidizable materials in low earth orbit. C.E.

AB9-51124\* National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, TX.

##### LABORATORY INVESTIGATIONS INVOLVING HIGH-VELOCITY OXYGEN ATOMS

LUBERT J. LEGER, STEVEN L. KOONTZ, JAMES T. VISENTINE (NASA, Johnson Space Center, Houston, TX), and JON B. CROSS (Los Alamos National Laboratory, NM) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 393-404. refs  
Copyright

Facilities for measuring material reactive characteristics have been under development for several years and span the atom energy range from thermal to 5 eV, the orbital collision energy. One of the high-atom energy facilities (The High Intensity/Energy Atomic Oxygen Source) capable of simulating the reactive part of LEO is described, along with results of beam characterization and preliminary material studies. The oxygen atom beam source was a continuous wave plasma produced by focusing a high-power CO<sub>2</sub> laser through a lens system into a rare gas/molecular oxygen mixture chamber at elevated temperature. Material samples were exposed to the high velocity beam through an external feedthrough. The facility showed good stability in continued operation for more than 100 hours, producing fluences of 10 to the 21st to 10 to the 22nd atoms/sq cm. Reaction efficiencies and surface morphology have been measured for several materials at energies of 1.5 and 2.8 eV, matching with data generated from previous space flights. Activation energies for carbon and Kapton as measured in this facility were 800 cal/mole. C.E.

AB9-51125\* Physical Sciences, Inc., Andover, MA.

##### PULSED SOURCE OF ENERGETIC ATOMIC OXYGEN

GEORGE E. CALEDONIA and ROBERT H. KRECH (Physical Sciences, Inc., Andover, MA) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 405-413. Research supported by NASA. refs  
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A large area, high flux beam of energetic oxygen atoms, E about 5 eV, has been developed to study the interaction of atomic oxygen with materials appropriate for spacecraft in low earth orbit. A description of the operating conditions and characteristics of the beam along with typical sample irradiation results are provided. Author

#### AB9-51126

##### SPACECRAFT MATERIAL OXYGEN EROSION SIMULATION USING ION BEAMS

ANTHONY R. MARTIN and GARY PROUDFOOT (Culham Laboratory, Abingdon, England) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 415-424. refs  
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An ion-beam based erosion facility designed for low-energy high-flux operation is shown to provide an excellent qualitative and quantitative simulation of LEO oxygen erosion effects on spacecraft. Surface morphology changes for a wide range of materials are reported, with special attention given to the Kapton spacecraft material. The present system does not require large power or cooling supplies. The ability to vary the energy of the oxygen beam allows the study of reaction mechanisms occurring



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in space, and the ability to vary the fluence allows the dependence of reaction rate upon exposure duration in orbit to be investigated in a reasonable time scale. R.R.

ABR-51127

### EVALUATION OF COATINGS FOR ATOMIC OXYGEN PROTECTION IN LOW EARTH ORBIT

J. B. CROSS (Los Alamos National Laboratory, NM), E. H. LAN, and C. A. SMITH (McDonnell Douglas Astronautics Co., Huntington Beach, CA) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 425-433. refs  
Copyright

A technique has been developed to evaluate coatings for LEO atomic oxygen protection. The technique uses the oxidation of silver film as a detector for atomic oxygen penetration or diffusion through materials. The technique has been demonstrated to be highly sensitive for in situ atomic oxygen measurements. Preliminary results indicate that sputtered PTFE Teflon (0.1 micron) has a fluence lifetime of 10 to the 19th O-atoms/sq cm, and sputtered silicon dioxide (0.1 micron), aluminum oxide (0.1 micron), and SWS-V-10, a silicone, (4 micron) have fluence lifetimes of 10 to the 20th to 10 to the 21st O-atoms/sq cm. There are large variations in the fluence lifetime data for these coatings. Further investigations are underway to determine the failure mechanisms. Author

ABR-51128

### ATOMIC OXYGEN EFFECTS ON MATERIALS

W. D. MORISON, R. C. TENNYSON, J. B. FRENCH, T. BRAITHWAITE (Toronto, University, Canada), M. MORISAN (Montreal, Université, Montreal, Canada) et al. IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 435-452. Research supported by Auburn University and Ontario Institute for Space and Terrestrial Science. refs  
(Contract N60921-86-C-A226)  
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This report describes the development of an atomic oxygen 'neutral' beam facility using a 'SURFATRON' surface wave launcher that can produce beam energies between 2 and 3 eV, at flux levels as high as about 10 to the 17th atoms/sq cm-sec. A variety of materials were investigated, including carbon, thin-film dielectrics and graphite fiber-reinforced epoxy and thermoplastic composites. Material erosion was studied to obtain recession rates and reaction efficiencies R(e) as a function of incident beam energy and fluence. Thin-film dielectric property changes over a wide frequency range were also measured as a function of fluence. The validity of accelerated testing was demonstrated by comparing values of R(e) and SEM photomicrographs of surface morphology at different flux levels to available space flight results. Author

ABR-51129

### AN APPROACH TO LONG TERM PREDICTION OF THE ATOMIC OXYGEN EFFECT ON MATERIALS

A. DE ROOU (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 453-462. refs  
Copyright

A formulation is derived for the oxidation of materials under oxygen ion bombardment. The oxidation formula exhibits linear-parabolic characteristics and is tested on silver oxidized in a dc plasma as well as in an RF plasma. The oxidation constants derived are used to predict the degradation of silver under atomic oxygen attack experienced during the STS-8 flight. The results are close to the measured thickness loss. Thermal cycling and flaking of the oxide layer are introduced by specifying a limited oxide flake size. A life time prediction is made for silver

interconnectors present on the Space Telescope HEC solar array blanket using the degradation formula. The result shows a life time shorter than the required five years. Author

ABR-51130

### PLASMA-DEPOSITED MULTI-PURPOSE PROTECTIVE COATINGS FOR SPACE APPLICATIONS

J. E. KLEMBERG-SAPIEHA, M. R. WERTHEIMER (Ecole Polytechnique, Montreal, Canada), and D. G. ZIMCOK (CDC, Communications Research Centre, Ottawa, Canada) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 463-472. Research supported by NSERC and Ministère de l'Éducation du Québec. refs  
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The application of various thin film protective layers to polymers such as Kapton polyimide and epoxy resins which are used on spacecraft and which are vulnerable to attack by oxygen is considered. Protective films including amorphous hydrogenated silicon (a-Si:H) and inorganic silicon compounds are derived from volatile compounds via microwave glow discharge. These films provide excellent protection against atomic oxygen attack and possess attractive electrical and optical properties. The ability to control the electrical conductivity of a-Si:H over many order of magnitude by gas-phase doping allows the prevention of charge buildup, while assuring negligible refraction or attenuation of radio frequency waves incident on the coated material. R.R.

ABR-51131

### THE SPACECRAFT GLOW - A REVIEW

BYRON DAVID GREEN (Physical Sciences, Inc., Andover, MA) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 477-491. Research supported by Physical Sciences, Inc. refs  
Copyright

This paper reviews the current state of knowledge on the glow observed above spacecraft surfaces which are exposed to the energetically impacting atmospheric flux. A variety of mechanisms including erosion are giving rise to this glow. The observations in several spectral regions are considered in light of the potential mechanisms responsible. Suggestions for key new observations are made. Author

ABR-51135

### PREPARATION OF METALLIC AND TRANSPARENT/CONDUCTIVE COATINGS ON FILMS FOR SPACE APPLICATION

WOLFGANG SIEFERT and WERNER MUELLER (Ranker GmbH und Co., Freiburg im Breisgau, Federal Republic of Germany) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 563-569. refs  
Copyright

Metallic and transparent/conductive coatings on polyester and polyimide are widely used on spacecraft as thermal-control material and to avoid electrostatic charging. The spacecraft is covered by a thermal blanket consisting of several polyester films, metallized on both sides, and on the top a polyimide film coated with ITO to avoid the electrostatic charging. For the preparation of the metallized film, rollcoaters for thermal evaporation are used. The transparent/conductive ITO layer is made by a sputter rollcoating machine. Author

ABR-51137

### ANOMALOUS CURRENT COLLECTION TO HIGH VOLTAGE ANODES IN THE SPACE ENVIRONMENT DUE TO SECONDARY ELECTRON EMISSION

DANIEL E. HASTINGS (MIT, Cambridge, MA) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-9, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 583-588. refs  
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The physics of a positively biased conductor surrounded by dielectrics in contact with plasma is investigated. It is shown that, due to the presence of secondary emission from the surrounding dielectrics, the voltage of the surfaces near the conductor can be bistable. One of the bistable solutions always has very low secondary emission, while the other has high secondary emission. The secondary current emitted from the neighboring dielectrics is collected by the conductor. When the voltage on the dielectric undergoes a transition from one bistable solution to another, this is seen as a concomitant increase in the current collected to the conductor. A theoretical treatment is presented for a conductor surrounded by dielectrics such as silicon dioxide and applied to explain the snapover effect observed on high-voltage solar arrays. Author

AB9-51138

#### SPACECRAFT PAINT LAYER ELECTRICAL CHARACTERISTICS MEASUREMENTS BY THE LANGMUIR PROBE TECHNIQUE

JEAN-PIERRE LEBRETON (ESA, Space Science Dept., Noordwijk, Netherlands) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-8, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 589-598. refs  
Copyright

A method based on the Langmuir probe technique has been applied to the determination of the volume resistivity and the capacitance of paint layers of 10-100-micron thickness which are used as thermal coatings for the external surface of spacecraft skins. In the study, painted metallic substrates are used as Langmuir probes and are polarized in the -50 to +50 V range using three complementary methods. The volume resistivity of the white paint PCB-Z is shown to increase with the electric field applied across the layer, varying from  $30 \times 10$  to the 9th ohm m (for  $E = 0.5 \times 10$  to the 5th V/m) to  $3 \times 10$  to the 9th ohm m (for  $E = 2.8 \times 10$  to the 5th V/m). Tests results are also presented for the PCB-119 and PSG-120 coatings. R.R.

AB9-51139

#### COLD PLASMA AND GAMMA-IRRADIATED POLYMERS

J. GUASTAVINO, C. MAYOUX, A. YOUNSI (Toulouse III, Université, France), R. A. FOURACRE (Royal College, Glasgow, Scotland), and H. M. BANDFORD (Glasgow, University, East Kilbride, Scotland) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-8, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 599-605. Research supported by EEC.  
Copyright

A prestressed polyimide polymer was irradiated under a Co-60 source (1 MGy) in order to study the evolution of the electrical response of the material to thermodepolarization currents. A current maximum is observed following irradiation by low-energy electrons and ions working separately or in conjunction. The results have been compared with data obtained for irradiation under a glow discharge. The current peak noted near 130°C is interpreted as a relaxation phenomenon which is due to trapped charges. The sensitivity to low-energy species of the prestressed polymer is discussed. R.R.

AB9-51140

#### EFFECTS OF AMBIENT ELECTRON PLASMA ON SPACECRAFT CHARGING AND DISCHARGING

JOSEPH E. NANEVICZ, JEFFREY S. THAYER, and KATHY L. HEWITT (SRI International, Menlo Park, CA) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-8, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 607-616. refs  
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SRI has studied the charging and discharging of spacecraft surface materials in a number of laboratory simulations. Recently, the laboratory spacecraft-charging-simulation facility was upgraded to permit the generation of a cool plasma in the test chamber. This is accomplished using a multipactor breakdown to ionize gas

and allowing the discharge products to simply diffuse throughout the test chamber. This facility is being used in a series of tests to investigate the importance of incorporating a cool plasma in laboratory studies of spacecraft charging. The paper describes the simulation facility in detail, giving particular attention to the two charged particle sources. Results obtained to date in experiments with quartz optical solar collector (OSR) panels and with second-surface Kapton thermal control materials are presented and discussed. Author

AB9-51145

#### MICROMETEOROID INTERACTIONS WITH SOLAR ARRAYS

K. BOGUS (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands), F. KRUEGER (Ingenieurbüro Krueger, Darmstadt, Federal Republic of Germany), M. ROTT (Muenchen, Technische Universität, Munich, Federal Republic of Germany), E. SCHNEIDER (Fraunhofer-Institut für Kurzelektrodynamik, Freiburg im Breisgau, Federal Republic of Germany), and H. THIEMANN (Physikalisch-Technische Studien GmbH, Freiburg im Breisgau, Federal Republic of Germany) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-8, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 675-686. refs  
(Contract ESA-7418/87/NL/1W/3C)  
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Solar array electrical failures observed in orbit on geostationary satellites suggest micrometeorite induced damage phenomena. Ground tests simulating micrometeorites were performed to study the interaction with a representative test sample. First results support the hypothesis of micrometeoroid induced electrical failure mechanisms. Author

AB9-51146

#### DEVELOPMENT OF AND INITIAL RESULTS FROM A HIGH FLUENCE, HIGH VELOCITY ATOMIC OXYGEN SOURCE

M. KINERSLEY, J. STARK (Southampton, University, England), and B. SWINYARD (SERC, Rutherford Appleton Laboratory, Didcot, England) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-8, 1988, Proceedings, Toulouse, France, Cepadues Editions, 1989, p. 701-710. refs  
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The development of an atomic oxygen source capable of achieving a source flux of greater than  $10^{14}$  to the 14th oxygen atoms/sq cm per s at a velocity of about 4.5 km/s is reported. The inherent flexibility of this source allows material evaluations to be made under different species exposure, including atomic nitrogen and oxides of nitrogen. The source facility instrumentation makes possible species identification, species energy identification, and the identification of surface reaction products from atomic oxygen on a given material. Surface catalytic effects can be studied using the source, with application to materials evaluation for reentry vehicles such as Hermes. Results are presented for a lexan-based material which will be used for the low-energy X-ray filter on Rosat. R.R.

AB9-52066

#### THE INTERACTION OF A HOLLOW CATHODE WITH THE IONOSPHERE

L. IESS and M. DOBROWOLNY (CNR, Istituto di Fisica dello Spazio Interplanetario, Frascati, Italy) Physics of Fluids B (ISSN 0899-6221), vol. 1, Sept. 1989, p. 1880-1889. refs  
Copyright

The expansion of the plasma emitted by a hollow cathode source and its interaction with an ambient ionospheric plasma are described in a spherically symmetric, stationary, fluid model, which includes anomalous collisions due to ion acoustic or Buneman instability. Currents and potential profiles are self-consistently computed for different densities and polarizations of the hollow cathode plasma. The model indicates that the region where the potential has suprathermal values is quite large and that hollow cathodes strongly enhance the charge collection of a polarized

body from the ambient plasma. These results are significant to the problem of power generation via tethered systems in space.

Author

ABR-52117

# **INHIBITING SURFACE FLASHOVER FOR SPACE CONDITIONS USING MAGNETIC FIELDS**

RICHARD KORZEKWA, F. MARK LEHR, HERMANN G. KROMPHOLZ, and MAGNE KRISTIANSEN (Texas Tech University, Lubbock) IEEE Transactions on Plasma Science (ISSN 0093-3813), vol. 17, Aug. 1989, p. 612-615. Research supported by SDIO. refs

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The influence of dc and pulsed magnetic fields on dielectric surface breakdown is investigated using pulsed test voltages under space conditions. Prediction from the saturated surface avalanche breakdown model and the experimental results show magnetic insulation effects; i.e., an increase of the flashover voltage, at magnetic-field amplitudes as low as 0.1 T. The insulation effects depend on the dielectric material, ambient pressure, surface roughness, and presence of background plasma. In order to achieve magnetic insulation without a background plasma, it is sufficient to apply the magnetic field to the cathode region only. I.E.

ABR-52410

# **NONSTEADY INTERACTION OF PLASMA WITH BODIES MOVING IN SPACE**

XIAO-QING LI (Purple Mountain Observatory, Nanjing, People's Republic of China) Astrophysics and Space Science (ISSN 0004-6403), vol. 153, no. 2, March 1989, p. 311-326. refs

Copyright

Nonsteady interactions between spacecraft and plasma are investigated in detail. The system of equations describing these interactions is obtained. It is shown that an electromagnetic soliton is excited via the modulational instabilities, which result from the radiation of antenna systems on the body which are the source of waves. In the meantime the density in far wake diminishes, and its disturbances becomes also a soliton if the pump wave is sufficiently intense. Author

ABR-53209\* Iowa Univ., Iowa City.

# **PLASMA DENSITY, TEMPERATURE AND TURBULENCE IN THE WAKE OF THE SHUTTLE ORBITER**

A. C. TRIBBLE, J. S. PICKETT, N. D'ANGELO (Iowa, University, Iowa City), and G. B. MURPHY (California Institute of Technology, Jet Propulsion Laboratory, Pasadena; Iowa, University, Iowa City) Planetary and Space Science (ISSN 0032-0633), vol. 37, Aug. 1989, p. 1001-1010. refs

(Contract NAQ3-449; NAS8-32807)

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In situ observations of the plasma density, temperature, and turbulence in the near wake, midwake, and far wake of the Shuttle Orbiter are presented. The results show that the plasma disturbances produced by the passage of the Orbiter extend downstream for a distance of several hundred meters behind the Orbiter. It is found that the electron density profile exhibits nonmonotonic behavior, and that most of the 6-40-Hz turbulence in the wake is confined to a region about 20 m downstream of the Orbiter. The saturation  $\Delta N_e/N_e$  spectra rapidly decline in the 10,000-100,000-Hz decade, both in the ambient ionosphere and in the wake. R.R.

ABR-53360\*# Los Alamos National Lab., NM.

# **NUCLEAR-POWERED SPACE DEBRIS SWEEPER**

JOHN D. METZGER, RENE J. LECLAIRE, JR., STEVEN D. HOWE, and KAREN C. BURGIN (Los Alamos National Laboratory, NM) Journal of Propulsion and Power (ISSN 0748-4658), vol. 5, Sept.-Oct. 1989, p. 582-590. Research supported by NASA. Previously announced in STAR as N88-24380. refs

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Future spacecraft design will be affected by collisions with man-made debris orbiting the earth. Most of this orbital space debris comes from spent rocket stages. It is projected that the

source of future debris will be the result of fragmentation of large objects through hypervelocity collisions. Orbiting spacecraft will have to be protected from hypervelocity debris in orbit. The options are to armor the spacecraft, resulting in increased mass, or actively removing the debris from orbit. An active space debris sweeper is described which will utilize momentum transfer to the debris through laser-induced ablation to alter its orbital parameters to reduce orbital lifetime with eventual entry into the earth's atmosphere where it will burn. The paper describes the concept, estimates the amount of velocity change ( $\Delta V$ ) that can be imparted to an object through laser-induced ablation, and investigates the use of a neutral particle beam for the momentum transfer. The space sweeper concept could also be extended to provide a collision avoidance system for the space station and satellites, or could be used for collision protection during interplanetary travel. Author

ABR-54218

# **SPACE ENVIRONMENTAL FACTORS AFFECTING RESPONSES TO RADIATION AT THE CELLULAR LEVEL**

H. PLANET, Y. GAUBIN, B. PIANEZZI, and G. GASSET (Toulouse III, Université, France) (COSPAR, Plenary Meeting, 27th, Topical Meetings and Workshop XIX on Life Sciences and Space Research XXIII(4) - Radiation Biology, Espoo, Finland, July 18-29, 1988) Advances in Space Research (ISSN 0273-1177), vol. 9, no. 10, 1989, p. 157-160. refs

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Previous space experiments suggest a high value for the RBE of cosmic radiation. A possible explanation could be a change in cell radiosensitivity due to the combined effect of radiation and other factors related to the space environment and space flight. Results of the EXOBLOC II experiment support this assumption. On earth, vibrations or accelerations applied before or after irradiation can change the responses to radiation. Microgravity could be the main factor affecting the radiosensitivity and DNA repair, but this hypothesis must be confirmed by additional experiments. Author

ABR-54222

# **COMBINED EFFECTS OF RADIATION AND TRAUMA**

OTFRIED MESSERSCHMIDT (Chirurgische Klinik Innenstadt und Chirurgische Poliklinik, Munich, Federal Republic of Germany) (COSPAR, Plenary Meeting, 27th, Topical Meetings and Workshop XIX on Life Sciences and Space Research XXIII(4) - Radiation Biology, Espoo, Finland, July 18-29, 1988) Advances in Space Research (ISSN 0273-1177), vol. 9, no. 10, 1989, p. 197-201. refs

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Wounds or burns which, in general, do not cause septicemia could become entrance ports for bacteria when animals are exposed to whole-body irradiation. Thrombocytopenia is the reason for hemorrhages in wounds. The susceptibility to shock is increased considerably in combined injuries and the formation of callus in the bone fractures is significantly delayed. The healing of wounds and burns in the initial phase of the radiation syndrome does not always differ from healing in the nonirradiated organism. However, a few days or weeks later very serious wound infections and hemorrhages can occur. The additional injuries almost always worsen the development and prognosis of radiation-induced disease. The recommended treatment for combined injuries will differ in many respects from the treatment of wounds and burns or the radiation syndrome. Author

ABR-54227\* Rockwell International Corp., Houston, TX.

# **A PARAMETRIC STUDY OF SPACE RADIATION EXPOSURES TO CRITICAL BODY ORGANS FOR LOW EARTH ORBIT MISSIONS**

W. ATWELL, E. R. BEEVER (Rockwell International Corp., Houston, TX), and A. C. HAROY (NASA, Johnson Space Center, Houston, TX) (COSPAR, Plenary Meeting, 27th, Topical Meetings and Workshop XIX on Life Sciences and Space Research XXIII(4) - Radiation Biology, Espoo, Finland, July 18-29, 1988) Advances in Space Research (ISSN 0273-1177), vol. 9, no. 10, 1989, p.



243-245. refs

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It is shown that it is possible to calculate the extent of the exposure to space radiation of a specific body organ. Using a computerized anatomical man model and models of radiation environments and spacecraft shielding, a parametric study was carried out for several Space Shuttle scenarios. The dose equivalent data for several blood-forming organ locations are presented (for a solar-minimum epoch) as a function of altitude and the shielding material, and the results are compared with the NASA crew exposure limits for these body organs. I.S.

A89-54228

# SPACE RADIATION DOSIMETRY WITH ACTIVE DETECTIONS FOR THE SCIENTIFIC PROGRAM OF THE SECOND BULGARIAN COSMONAUT ON BOARD THE MIR SPACE STATION

TS. P. DACHEV, IU. N. MATVICHUK, I. V. SEMKOVA, R. T. KOLEVA, B. LOICHEV (B'garska Akademiya na Naukite, Tsentraina Laboratoriya za Kosmicheski Izsledvaniya, Sofia, Bulgaria) et al. (COSPAR, Plenary Meeting, 27th, Topical Meetings and Workshop XIX on Life Sciences and Space Research XXIII(4) - Radiation Biology, Espoo, Finland, July 18-29, 1988) *Advances in Space Research* (ISSN 0273-1177), vol. 9, no. 10, 1989, p. 247-251. refs

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A dosimetry-radiometry system has been developed at the Space Research Institute of the Bulgarian Academy of Science to measure the fluxes and dose rates on the flight of the second Bulgarian cosmonaut. The dosimetry system is designed for monitoring the different space radiations, such as solar cosmic rays and trapped particles in the earth radiation belts. The system consists of a battery operated small size detector unit and a 'read-write' and telemetry microcomputer unit. The sensitivity of the instrument permits high resolution measurements of the flux and dose rate along the track of the Mir space station. The paper presents the initial results for the period of the flight between June 7-17, 1988. Author

A89-54229

# MODELING OF THE RADIATION EXPOSURE DURING THE FLIGHT OF THE SECOND BULGARIAN COSMONAUT ON BOARD THE MIR SPACE STATION

TS. P. DACHEV, IU. N. MATVICHUK, N. G. BANKOV, R. T. KOLEVA, P. I. VELLINOV (B'garska Akademiya na Naukite, Tsentraina Laboratoriya za Kosmicheski Izsledvaniya, Sofia, Bulgaria) et al. (COSPAR, Plenary Meeting, 27th, Topical Meetings and Workshop XIX on Life Sciences and Space Research XXIII(4) - Radiation Biology, Espoo, Finland, July 18-29, 1988) *Advances in Space Research* (ISSN 0273-1177), vol. 9, no. 10, 1989, p. 253-255. refs

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An experiment involving active detection of space radiation was carried out in the Space Research Institute (SRI) of Bulgarian Academy of Sciences, in preparation of the flight of the second Bulgarian cosmonaut. The radiations that would be encountered on the flight were modeled, including solar and Galactic cosmic rays and the particle radiation in the earth's radiation belts. The dose rate was calculated for these different radiations behind the shielding of the space station. The variations in dose rates over the period of the flight were calculated and compared with measurements made during the orbit of the Mir space station. The calculated and measured dose rates agreed within 15.35 percent. Author

A89-54230\* Severn Communications Corp., Millersville, MD.

# MODEL ANALYSIS OF SPACE SHUTTLE DOSIMETRY DATA

J. R. LETAW (Severn Communications Corp., Millersville, MD), R. SILBERBERG, C. H. TSAO (U.S. Navy, E. O. Hulbert Center for Space Research, Washington, DC), and E. V. BENTON (San Francisco, University, CA) (COSPAR, Plenary Meeting, 27th, Topical Meetings and Workshop XIX on Life Sciences and Space Research XXIII(4) - Radiation Biology, Espoo, Finland, July 18-29,

1988) *Advances in Space Research* (ISSN 0273-1177), vol. 9, no. 10, 1989, p. 257-260. refs

(Contract DPR-T3452P; N00014-87-C-2251)

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An extensive model analysis of plastic track detector measurements of high-LET particles on the Space Shuttle has been performed. Three Shuttle flights: STS-51F (low-altitude, high-inclination), STS-51J (high-altitude, low-inclination), and STS-61C (low-altitude, low-inclination) are considered. The model includes contributions from trapped protons and Galactic cosmic radiation, as well as target secondary particles. Target secondaries, expected to be of importance in thickly shielded space environments, are found to be a significant component of the measured LET (linear energy transfer) spectra. Author

A89-54231\* National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, MD.

# EFFECTIVE RADIATION REDUCTION IN SPACE STATION AND MISSIONS BEYOND THE MAGNETOSPHERE

THOMAS M. JORDAN (EMP Consultants, Galhensburg, MD) and E. G. STASSINOPOULOS (NASA, Goddard Space Flight Center, Greenbelt, MD) (COSPAR, Plenary Meeting, 27th, Topical Meetings and Workshop XIX on Life Sciences and Space Research XXIII(4) - Radiation Biology, Espoo, Finland, July 18-29, 1988) *Advances in Space Research* (ISSN 0273-1177), vol. 9, no. 10, 1989, p. 261-274. refs

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This paper investigates the efficiency of low- and high-atomic number materials used as protective shields against biologically effective radiation in doses equivalent to those expected in low-earth-orbit and interplanetary manned missions. Results are presented on calculations for single-material shields from polyethylene, water, Be, Al, Fe, and Ta and multilayer shields made from the combinations of any two or any three of these materials, for both LEO and interplanetary conditions. It is shown that, whereas for protons and Galactic cosmic rays the ordering of shield materials has a negligible effect, for electrons and secondary bremsstrahlung, both the order and the composition are important parameters. It was found that low-atomic-number materials are most effective shields against protons and galactic cosmic rays, and are most effective in decreasing bremsstrahlung production, while high-atomic-number shields are the best attenuators of both primary electrons (if the dose is dominated by primary electrons) and secondary bremsstrahlung (if this is produced). I.S.

A89-54233

# PPS-87 - A NEW EVENT ORIENTED SOLAR PROTON PREDICTION MODEL

D. F. SMART and M. A. SHEA (USAF, Geophysics Laboratory, Bedford, MA) (COSPAR, Plenary Meeting, 27th, Topical Meetings and Workshop XIX on Life Sciences and Space Research XXIII(4) - Radiation Biology, Espoo, Finland, July 18-29, 1988) *Advances in Space Research* (ISSN 0273-1177), vol. 9, no. 10, 1989, p. 281-284. refs

Copyright

A new event-oriented solar proton prediction model has been developed and implemented at the USAF Space Environment forecast facility. This new model generates predicted solar proton time-intensity profiles for a number of user adjustable energy ranges and is also capable of making predictions for the heavy ion flux. The computer program is designed so a forecaster can select inputs based on the data available in near real-time at the forecast center as the solar flare is occurring. The predicted event amplitude is based on the EM emission parameters of the solar flare (either microwave or soft X-ray emission) and the solar flare position on the sun. The model also has an update capability, where the forecaster can normalize the prediction to actual spacecraft observations of spectral slope and particle flux as the event is occurring, in order to more accurately predict the future time-intensity profile of the solar particle flux. Besides containing improvements in the accuracy of the predicted energetic particle event onset time and magnitude, the new model converts the

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predicted solar particle flux into an expected radiation dose that might be experienced by an astronaut during EVA activities or inside the Space Shuttle. Author

**A89-54343**

### SPACE RADIATION AND THERMAL CYCLE EFFECTS ON GRAPHITE/EPOXY COMPOSITE FOR CANDIDATE MATERIAL OF SPACEPLANE AND SPACECRAFT

YOUSUKE NAGAO, T. KAMIYAMA, N. SUGAHARA (Fuji Heavy Industries, Ltd., Utsunomiya, Japan), T. SASUGA, T. SEGUCHI (Japan Atomic Energy Research Institute, Takasaki) et al. In: International Conference on Hypersonic Flight in the 21st Century, 1st, Grand Forks, ND, Sept. 20-23, 1988, Proceedings. Grand Forks, ND, University of North Dakota, 1988, p. 209-218. refs

Copyright

An evaluation is made of intense irradiation and thermal cycling effects on the mechanical properties of two candidate CFRP composites for aircraft and aerospacecraft use: T-300/3601 and 'tough' IM-6/R6376. Both were subjected to up to 10 MGy of electron irradiation, and up to 3000 thermal cycles; mechanical testing of the composite laminate samples was then conducted in the -90 to 110 C temperature range, in order to ascertain the presence and extent of microcracking. Microcracking was observed in the T-300/3601 laminates after only 1000 thermal cycles, demonstrating the superiority of the 'tough' composite material.

O.C.

**A89-54365**

### SPACE DEBRIS - A DEFINITE HAZARD TO HYPERSONIC FLIGHT

JOHN GRAHAM (USAF, North Dakota, University, Minot) In: International Conference on Hypersonic Flight in the 21st Century, 1st, Grand Forks, ND, Sept. 20-23, 1988, Proceedings. Grand Forks, ND, University of North Dakota, 1988, p. 403-408. refs

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The hazard of space debris for hypersonic flight in the high atmospheric regions and in LEO is discussed. The typical types of space debris are described and the orbits which are particularly hazardous to hypersonic flight are identified. The distribution of space debris is examined and a damage potential analysis of a flight from New York City to the Space Station with a return landing in Tokyo is presented.

R.B.

**N89-20158\*** National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.

### THE MAGNETIC FIELD INVESTIGATION ON CLUSTER

A. BALOGH, S. W. H. COWLEY, D. J. SOUTHWOOD, G. MUSMANN, H. LUHR, F. M. NEUBAUER, K.-H. GLASSMEIER, W. RIEDLER, M. F. HEYN (Oesterreichische Akademie der Wissenschaften, Vienna), M. H. ACUNA et al. In: ESA, The Cluster Mission: Scientific and Technical Aspects of the Instruments p. 15-20 Oct. 1988 Prepared in cooperation with California Univ., Los Angeles, Danish Space Research Inst., Lyngby, Centre National d'Etudes des Telecommunications, Issy-les-Moulineaux, France, and JPL, Pasadena, CA

Avail: NTIS HC A06/MF A01; ESA Publications Div., ESTEC, Noordwijk, Netherlands, \$10 US or 25 Dutch guilders CSCL 04A

The magnetic field investigation of the Cluster four-spacecraft mission is designed to provide intercalibrated measurements of the B magnetic field vector. The instrumentation and data processing of the mission are discussed. The instrumentation is identical on the four spacecraft. It consists of two triaxial fluxgate sensors and of a failure tolerant data processing unit. The combined analysis of the four spacecraft data will yield such parameters as the current density vector, wave vectors, and the geometry and structure of discontinuities.

ESA

**N89-20189\*** Royal Inst. of Tech., Stockholm (Sweden). Dept. of Plasma Physics.

### MEASUREMENT OF QUASI-STATIC AND LOW FREQUENCY ELECTRIC FIELDS ON THE VIKING SATELLITE

L. P. BLOCK, CARL-GUNNE FAELTHAMMAR, P.-A. LINDQVIST, G. T. MARKLUND, F. S. MOZER, and A. PEDERSEN (European

Space Agency, European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) Mar. 1987 19 p. Sponsored by the Swedish Board for Space Activities, Stockholm, Sweden (TRITA-EPP-87-02; ISSN-0348-7539; ETN-89-93725) Avail: NTIS HC A03/MF A01

The instrument for measurement of quasi-static and low frequency (dc and slowly varying) electric fields on the Swedish Viking satellite is described. The instrument uses 3 spherical probe pairs to measure the full three-dimensional electric field vector with 18.75 ms time resolution. The probes are kept near plasma potential by means of a controllable bias current. A guard covering part of the booms is biased to a negative voltage to prevent photoelectrons escaping from the probes from reaching the satellite body. Current-voltage sweeps are performed to determine the plasma density and temperature and to select the optimal bias current. The bias currents to the probes and the voltage offset on the guards as well as the current-voltage sweeps are controlled by an on-board microprocessor which can be programmed from the ground and allows great flexibility.

ESA

**N89-21015\*** Photometrics, Inc., Woburn, MA.

### EXCITATION AND DIAGNOSTICS OF OPTICAL CONTAMINATION IN THE SPACECRAFT ENVIRONMENT Final Report, 13 Aug. 1985 - 30 Jun. 1988

I. L. KOFISKY, J. L. BARRETT, T. E. BROWNRIGG, P. N. MONICHELL, and N. H. TRAN 1 Jul. 1988 158 p

(Contract F19628-85-C-0148)

(AD-A202429; PHM-88-06; AFGL-TR-88-0293) Avail: NTIS HC A06/MF A01 CSCL 22/5

The ultraviolet and infrared contaminant glows produced by spacecraft traversing the thermosphere are identified and their spatial extents and brightnesses estimated from laboratory reaction-rate data, in support of planning of systematic spectroradiometric measurements from space shuttle. A formalism is developed for calculating radiances and irradiances of the emissions from metastable molecules formed at vehicle surfaces exposed to the atmosphere, which serves in selecting the view projections and angular fields of optical sensors.

GRA

**N89-21100\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

### EVALUATION OF ATOMIC OXYGEN RESISTANT PROTECTIVE COATINGS FOR FIBERGLASS-EPOXY COMPOSITES IN LEO

SHARON K. RUTLEDGE, PHILLIP E. PAULSEN, and JOYCE A. BRADY (Sverdrup Technology, Inc., Cleveland, OH.) 1989 13 p. Presented at the 34th SAMPE Technical Conference, Reno, NV, 8-11 May 1989

(NASA-TM-101955; E-4649; NAS 1.15:101955) Avail: NTIS HC A03/MF A01 CSCL 11/2

Fiberglass-epoxy composite masts are the prime structural members for the Space Station Freedom solar array. At the altitude where Space Station Freedom will operate, atomic oxygen atoms are the most predominant species. Atomic oxygen is highly reactive and has been shown to oxidize organic and some metallic materials. Tests with random and directed atomic oxygen exposure have shown that the epoxy is removed from the composite exposing brittle glass fibers which could be easily removed from the surface where they could contaminate Space Station Freedom Systems. Protection or fiber containment systems; inorganic based paints, aluminum braid, and a metal coating; were evaluated for resistance to atomic oxygen, vacuum ultraviolet radiation, thermal cycling, and mechanical flexing. All appeared to protect well against atomic oxygen and provide fiber containment except for the single aluminum braid covering. UV radiation resistance was acceptable and in general, thermal cycling and flexure had little to no effect on the mass loss rate for most coatings.

Author

**N89-21104\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

### SIMULATION OF THE LOW EARTH ORBITAL ATOMIC OXYGEN INTERACTION WITH MATERIALS BY MEANS OF AN OXYGEN ION BEAM

BRUCE A. BANKS, SHARON K. RUTLEDGE, PHILLIP E.

PAULSEN, and THOMAS J. STEUBER (Sverdrup Technology, Inc., Cleveland, OH.) 1989 32 p Presented at the 18th Annual Symposium on Applied Vacuum Science and Technology, Clearwater Beach, FL, 6-8 Feb. 1989; sponsored by American Vacuum Society  
(NASA-TM-101971; E-4671; NAS 1.15:101971) Avail: NTIS HC A03/MF A01 CSCL 11/3

Atomic oxygen is the predominant species in low-Earth orbit between the altitudes of 180 and 650 km. These highly reactive atoms are a result of photodissociation of diatomic oxygen molecules from solar photons having a wavelength less than or equal to 2430 Å. Spacecraft in low-Earth orbit collide with atomic oxygen in the 3P ground state at impact energies of approximately 4.2 to 4.5 eV. As a consequence, organic materials previously used for high altitude geosynchronous spacecraft are severely oxidized in the low-Earth orbital environment. The evaluation of materials durability to atomic oxygen requires ground simulation of this environment to cost effectively screen materials for durability. Directed broad beam oxygen sources are necessary to evaluate potential spacecraft materials performance before and after exposure to the simulated low-Earth orbital environment. This paper presents a description of a low energy, broad oxygen ion beam source used to simulate the low-Earth orbital atomic oxygen environment. The results of materials interaction with this beam and comparison with actual in-space tests of the same materials will be discussed. Resulting surface morphologies appear to closely replicate those observed in space tests. Author

**N89-21246\*** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.  
**OBLIQUE HYPERVELOCITY IMPACT RESPONSE OF DUAL-SHEET STRUCTURES**  
WILLIAM P. SCHONBERG (Alabama Univ., Huntsville.) and ROY A. TAYLOR Jan. 1989 44 p  
(NASA-TM-100358; NAS 1.15:100358) Avail: NTIS HC A03/MF A01 CSCL 20/11

The results of a continuing investigation of the phenomena associated with the oblique hypervelocity impact of spherical projectiles onto multi-sheet aluminum structures are given. A series of equations that quantitatively describes these phenomena is obtained through a regression of experimental data. These equations characterize observed ricochet and penetration damage phenomena in a multi-sheet structure as functions of geometric parameters of the structure and the diameter, obliquity, and velocity of the impacting projectile. Crater damage observed on the ricochet witness plates is used to determine the sizes and speeds of the ricochet debris particles that caused the damage. It is observed that the diameter of the most damaging ricochet debris particle can be as large as 40 percent of the original particle diameter and can travel at speeds between 24 percent and 36 percent of the original projectile impact velocity. The equations necessary for the design of shielding panels that will protect external systems from such ricochet debris damage are also developed. The dimensions of these shielding panels are shown to be strongly dependent on their inclination and on their circumferential distribution around the spacecraft. Author

**N89-21750\*** Alabama Univ., Huntsville. Dept. of Mechanical Engineering.  
**FURTHER INVESTIGATIONS OF OBLIQUE HYPERVELOCITY IMPACT PHENOMENA**  
WILLIAM P. SCHONBERG In Alabama Univ., Research Reports: 1988 NASA/ASEE Summer Faculty Fellowship Program 45 p Dec. 1988  
Avail: NTIS HC A99/MF E03 CSCL 13/9

The results of a continuing investigation of the phenomena associated with the oblique hypervelocity impact of spherical projectiles onto multi-sheet aluminum structures are described. A series of equations that quantitatively describes these phenomena is obtained through a regression of experimental data. These equations characterize observed ricochet and penetration damage phenomena in a multi-sheet structure as functions of the geometric parameters of the structure and the diameter, obliquity, and velocity

of the impacting projectile. Crater damage observed on the ricochet witness plates is used to determine the sizes and speeds of the ricochet debris particles that caused the damage. It is shown that, in general, the most damaging ricochet debris particle is approximately 0.25 cm (0.10 in) in diameter and travels at the speed of approximately 2.1 km/sec (6,890 ft/sec). The equations necessary for the design of shielding panels that will protect external systems from such ricochet debris damage are also developed. The dimensions of these shielding panels are shown to be strongly dependent on their inclination and on their circumferential distribution around the spacecraft. It is concluded that obliquity effects of high-speed impacts must be considered in the design of any structure exposed to the meteoroid and space debris environment. Author

**N89-21826\*** Aerospace Corp., El Segundo, CA. Space Sciences Lab.  
**THE RADIATION DOSE IN A MOLNIYA-TYPE ORBIT**  
J. B. BLAKE and J. E. COX 1 Dec. 1988 13 p  
(Contract F04701-85-C-0086)  
(AD-A204202; TR-0086(3940-05)-4; SD-TR-88-107) Avail: NTIS HC A03/MF A01 CSCL 22/1

A pair of dosimeters aboard satellites in Molniya orbit have made measurements of the radiation dose under 0.69 gm/sq.cm of aluminum. The measured dose was substantially less than that predicted by the NASA AE-8 and AP-8 models. The cause of the difference cannot be determined with certainty. One possibility is the AP-8 is in agreement with the observations and that AE-8 leads to a substantial overestimate of the dose due to electrons. GRA

**N89-21967** Centre National d'Etudes Spatiales, Toulouse (France).  
**EVALUATION OF VLSI FOR SPACE APPLICATIONS**  
[EVALUATION DE VLSI POUR UNE UTILISATION SPATIALE]  
THIERRY CHAPUIS and JEAN-LOUIS VENTURIN In its Quality, Components and Technological Analysis p 545-595 Aug. 1988  
In FRENCH; ENGLISH summary  
Copyright Avail: CEPADUES-Editions, 111 Rue Nicolas-Vauquelin, 31100 Toulouse, France

Methods of assessing the sensitivity of a component regarding radiation, and finding out parameters mandatory to calculate the level of stress encountered during the mission are presented. An assessment of SRAM 16 kbits VLSI circuit is also presented. The evolution of memories correlated to irradiation with heavy ions does not show a significant variation of the upset as a function of dose. ESA

**N89-21968** Centre d'Etudes et de Recherches, Toulouse (France).  
**IRRADIATIONS: TOTAL DOSES. HEAVY IONS**  
JACQUES BOURRIEU and DIDIER FALGUERE In its Quality, Components and Technological Analysis p 597-687 Aug. 1988  
In FRENCH; ENGLISH summary  
Copyright Avail: CEPADUES-Editions, 111 Rue Nicolas-Vauquelin, 31100 Toulouse, France

The main characteristics of the radiation environment (trapped p(+) and e(-), heavy ions, and p(+)) from solar events, galactic cosmic rays) are reviewed. The interaction with matter, slowing down, stopping power, range, and method used for the dose and shielding computation are described as well as characteristic results. Computation and simulation methods for the evaluation of heavy ion effects are presented including single event upset and latch-up. The tests required to assess the performance of a component under heavy ion exposure are discussed. ESA

**N89-21969** Grenoble-1 Univ. (France). Lab. Circuits et Systemes.  
**TECHNIQUES OF HEAVY ION TESTING FOR PROGRAMMABLE VLSI**  
R. VELAZCO and A. PROVOST-GRELLIER In CNES, Quality, Components and Technological Analysis p 689-706 Aug. 1988



## 17 SPACE ENVIRONMENT

In FRENCH; ENGLISH summary

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A strategy devoted to reduce the most critical upset space radiation effect is presented. The method addresses programmable integrated circuits, that is circuits able to execute an instruction or command set. The experimental results obtained with circuits which are well known as being sensitive to upset show the reliability and flexibility of the system. ESA

**N89-22638\*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

### ORBITAL DEBRIS ENVIRONMENT FOR SPACECRAFT DESIGNED TO OPERATE IN LOW EARTH ORBIT

DONALD J. KESSLER, ROBERT C. REYNOLDS, and PHILLIP D. ANZ-MEADOR 1 Sep. 1988 19 p Prepared in cooperation with Lockheed Engineering and Sciences Co., Houston, TX (NASA-TM-100471; NAS 1.15:100471) Avail: NTIS HC A03/MF A01 CSCL 22/2

The orbital debris environment model is intended to be used by the spacecraft community for the design and operation of spacecraft in low Earth orbit. This environment, when combined with material-dependent impact tests and spacecraft failure analysis, is intended to be used to evaluate spacecraft vulnerability, reliability, and shielding requirements. The environment represents a compromise between existing data to measure the environment, modeling of this data to predict the future environment, the uncertainty in both measurements and modeling, and the need to describe the environment so that various options concerning spacecraft design and operations can be easily evaluated.

Author

**N89-22649\*** Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.

### SPACECRAFT CHARGE AS A SOURCE OF ELECTRICAL POWER FOR SPACECRAFT M.S. Thesis

WAYNE GALE Nov. 1988 107 p (AD-A202621; AD-E900870; AFIT/GSO/ENP/88D-2) Avail: NTIS HC A06/MF A01 CSCL 22/2

This thesis examines the suitability of spacecraft charge, collected at geosynchronous altitude, as a source of electrical power for spacecraft. An analytical plasma probe model is used to describe the flux of charged particle currents on two isolated (conductive) hemispheres of a spacecraft. Surface potentials are evaluated for both a body-stabilized and spin-stabilized spacecraft under average and worst case plasma conditions. A discharge current is simulated, between differentially charged surfaces, to examine the current flow required to balance the surface potentials. This current approximates the maximum current flow available from the spacecraft charge. The results show that surface potential differences can be large in in worst case plasma conditions, but the current available is too small to be useful as a power source. The discharge current does scale up in proportion to spacecraft surface area exposed to the plasma; however, the design of large conductive spacecraft surfaces is a problem in itself. GRA

**N89-22682\*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

### IN-SPACE TECHNOLOGY DEVELOPMENT: ATOMIC OXYGEN AND ORBITAL DEBRIS EFFECTS

JAMES T. VISENTINE and ANDREW E. POTTER, JR. May 1989 42 p (NASA-TM-102154; S-593; NAS 1.15:102154) Avail: NTIS HC A03/MF A01 CSCL 07/1

Earlier Shuttle flight experiments have shown atomic oxygen within the orbital environment can interact with many materials to produce surface recession and mass loss and combine catalytically with other constituents to generate visible and infrared glows. In addition to these effects, examinations of returned satellite hardware have shown many spacecraft materials are also susceptible to damage from high velocity impacts with orbital space debris. These effects are of particular concern for large, multi-mission spacecraft, such as Space Station and SDI

operational satellites, that will operate in low-Earth orbit (LEO) during the late 1990's. Not only must these spacecraft include materials and exterior coatings that are resistant to atomic oxygen surface interactions, but these materials must also provide adequate protection against erosion and pitting that could result from numerous impacts with small particles (less than 100 microns) of orbital space debris. An overview of these concerns is presented, and activities now underway to develop materials and coatings are outlined that will provide adequate atomic protection for future spacecraft. The report also discusses atomic oxygen and orbital debris flight experiments now under development to expand our limited data base, correlate ground-based measurements with flight results, and develop an orbital debris collision warning system for use by future spacecraft. Author

**N89-23526\*** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

### NASA/SDIO SPACE ENVIRONMENTAL EFFECTS ON MATERIALS WORKSHOP, PART 1

LOUIS A. TEICHMAN, comp. and BLAND A. STEIN, comp. Washington May 1989 356 p Workshop held in Hampton, VA, 28 Jun. - 1 Jul. 1988 (NASA-CP-3035-PT-1; L-16575-PT-1; NAS 1.55:3035-PT-1) Avail: NTIS HC A16/MF A02 CSCL 11/7

The present state of knowledge regarding space environmental effects on materials is described and the knowledge gaps that prevent informed decisions on the best use of advanced materials in space for long-duration NASA and Strategic Defense Initiative Organization (SDIO) missions are identified. Establishing priorities for future ground-based and space-based materials research was a major goal. The end product was an assessment of the current state-of-the-art in space environmental effects on materials in order to develop a national plan for spaceflight experiments.

**N89-23529\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

### OVERVIEW OF ENVIRONMENTAL FACTORS

C. K. PURVIS In NASA, Langley Research Center, NASA/SDIO Space Environmental Effects on Materials Workshop, Part 1 p 5-24 May 1989 Avail: NTIS HC A16/MF A02 CSCL 11/7

The orbital environment is complex, dynamic, and comprised of both natural and system-induced components. Several environment factors are important for materials. Materials selection/suitability determination requires consideration of each and all factors, including synergisms among them. Understanding and evaluating these effects will require ground testing, modeling, and focused flight experimentation. Author

**N89-23531\*** Mission Research Corp., San Diego, CA.

### RADIATION EFFECTS IN SPACECRAFT ELECTRONICS

JAMES P. RAYMOND In NASA, Langley Research Center, NASA/SDIO Space Environmental Effects on Materials Workshop, Part 1 p 53-74 May 1989 (Contract N00014-85-C-2642) Avail: NTIS HC A16/MF A02 CSCL 09/3

Effects on the internal spacecraft electronics due to exposure to the natural and enhanced space radiation environment will be reviewed. The emphasis will be placed on the description of the nature of both the exposure environment and failure mechanisms in semiconductors. Understanding both the system environment and device effects is critical in the use of laboratory simulation environments to obtain the data necessary to design and qualify components for successful application. Author

**N89-23532\*** Rockwell International Corp., Seal Beach, CA.

### ENVIRONMENTAL EFFECTS ON SPACECRAFT MATERIALS

J. W. HAFFNER In NASA, Langley Research Center, NASA/SDIO Space Environmental Effects on Materials Workshop, Part 1 p 75-86 May 1989 Avail: NTIS HC A16/MF A02 CSCL 11/7

The effects on the natural space environments on materials are presented, which may be used for SDI applications. The current

state-of-the-art knowledge of those effects was studied, and a literature search, a questionnaire mailing, and some visits to NASA and Air Force research facilities were performed. Phase 2 will be a study of what materials may be used for SDI applications and to what natural space environments they may be vulnerable. Deficiencies in knowledge of the effects of the natural space environments on these materials are to be identified and recommendations are to be made to eliminate these knowledge deficiencies. Author

**N89-23534\*** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

#### THE LONG DURATION EXPOSURE FACILITY MATERIAL EXPERIMENTS

WILLIAM H. KINARD and JAMES L. JONES, JR. In *its* NASA/SDIO Space Environmental Effects on Materials Workshop, Part 1 p 101-105 May 1989

Avail: NTIS HC A16/MF A02 CSCL 11/7

In the early 1970s, the NASA Office of Aeronautics and Space Technology (OAST) approved the Long Duration Exposure Facility (LDEF) Project. The LDEF project provided NASA and other U.S. and foreign research organizations with opportunities to perform critical technology and science experiments in space using the LDEF and the Space Shuttle. Many of the experiments which were developed and are flying on the first LDEF mission are experiments to investigate the effects of the space environment on materials. An overview is provided for these materials experiments. The LDEF was placed in orbit by the shuttle orbiter Challenger in April 1984, and it was to have been retrieved approximately 1 year later. The Challenger accident, however, has delayed the retrieval more than 4 years. The LDEF retrieval is now manifested on Flight 32 in July 1989. Since the facility and experiments will have been in space almost 5-1/4 years when they are retrieved, they will be a national trove of science and technology data. Author

**N89-23535\*** National Oceanic and Atmospheric Administration, Boulder, CO. Solar-Terrestrial Physics Div.

#### TRENDS IN ENVIRONMENTALLY INDUCED SPACECRAFT ANOMALIES

DANIEL C. WILKINSON In *NASA, Langley Research Center, NASA/SDIO Space Environmental Effects on Materials Workshop, Part 1* p 123-131 May 1989

Avail: NTIS HC A16/MF A02 CSCL 22/2

The Spacecraft Anomaly Data Base was useful in identifying trends in anomaly occurrence. Trends alone do not provide quantitative testimony to a spacecraft's reliability, but they do indicate areas that command closer study. An in-depth analysis of a specific anomaly can be expensive and difficult without access to the spacecraft. Statistically verified anomaly trends can provide a good reference point to begin anomaly analysis. Many spacecraft experience an increase in anomalies during the period of several days centered on the solar equinox, a period that is also correlated with sun eclipse at geostationary altitude and an increase in major geomagnetic storms. Increase anomaly occurrence can also be seen during the local time interval between midnight and dawn. This local time interval represents a region in Earth's near space that experiences an enhancement in electron plasma density due to a migration from the magnetotail during or following a geomagnetic substorm. Author

**N89-23537\*** National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.

#### RETURNED SOLAR MAX HARDWARE DEGRADATION STUDY RESULTS

JACK J. TRILOLO and GILBERT W. OUSLEY In *NASA, Langley Research Center, NASA/SDIO Space Environmental Effects on Materials Workshop, Part 1* p 133-159 May 1989

Avail: NTIS HC A16/MF A02 CSCL 11/7

The Solar Maximum Repair Mission returned with the replaced hardware that had been in low Earth orbit for over four years. The materials of this returned hardware gave the aerospace community an opportunity to study the real-time effects of atomic

oxygen, solar radiation, impact particles, charged particle radiation, and molecular contamination. The results of these studies are summarized. Author

**N89-23539\*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

#### ENVIRONMENTAL DEFINITION OF THE EARTH'S NEUTRAL ATMOSPHERE

JAMES T. VISENTINE In *NASA, Langley Research Center, NASA/SDIO Space Environmental Effects on Materials Workshop, Part 1* p 179-195 May 1989

Avail: NTIS HC A16/MF A02 CSCL 13/2

Although number densities are low at altitudes where spacecraft typically operate, high orbital speeds result in incident fluxes and collisional energies large enough to interact with and degrade material surfaces. Global thermospheric models, when combined with orbital mechanics models, may be used to predict atomic oxygen fluence, or total integrated flux incidence on spacecraft surfaces. Fluence predictions, when used with STS materials reactivity measurements, provide reliable estimates of the oxidative effects on spacecraft surfaces. Author

**N89-23540\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

#### ATOMIC OXYGEN EFFECTS ON MATERIALS

BRUCE A. BANKS, SHARON K. RUTLEDGE, JOYCE A. BRADY, and JAMES E. MERROW (Ohio Univ., Athens.) In *NASA, Langley Research Center, NASA/SDIO Space Environmental Effects on Materials Workshop, Part 1* p 197-239 May 1989

Avail: NTIS HC A16/MF A02 CSCL 11/7

Understanding of the basic processes of atomic oxygen interaction is currently at a very elementary level. However, measurement of erosion yields, surface morphology, and optical properties for low fluences have brought about much progress in the past decade. Understanding the mechanisms and those factors that are important for proper simulation of low Earth orbit is at a much lower level of understanding. The ability to use laboratory simulations with confidence to quantifiably address the functional performance and durability of materials in low Earth orbit will be necessary to assure long-term survivability to the natural space environment. Author

**N89-23541\*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

#### ATOMIC OXYGEN EFFECTS ON SPACECRAFT MATERIALS: THE STATE OF THE ART OF OUR KNOWLEDGE

STEVEN L. KOONTZ In *NASA, Langley Research Center, NASA/SDIO Space Environmental Effects on Materials Workshop, Part 1* p 241-253 May 1989

Avail: NTIS HC A16/MF A02 CSCL 22/2

In the flight materials exposure data base extensive quantitative data is available from limited exposures in a narrow range of orbital environments. More data is needed in a wider range of environments as well as longer exposure times. Synergistic effects with other environmental factors; polar orbit and higher altitude environments; and real time materials degradation data is needed to understand degradation kinetics and mechanism. Almost no laboratory data exists from high fidelity simulations of the LEO environment. Simulation and test system are under development, and the data base is scanty. Theoretical understanding of hyperthermal atom surface reactions in the LEO environment is not good enough to support development of reliable accelerated test methods. The laser sustained discharge, atom beam sources are the most promising high fidelity simulation-test systems at this time. Author

**N89-23542\*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

#### THE LONG-TERM EFFECTS OF THE MICROMETEOROID AND ORBITAL DEBRIS ENVIRONMENTS ON MATERIALS USED IN SPACE

BURTON G. COUR-PALAIS In *NASA, Langley Research Center,*

## 17 SPACE ENVIRONMENT

NASA/SOIO Space Environmental Effects on Materials Workshop,  
Part 1 p 257-280 May 1989

Avail: NTIS HC A16/MF A02 CSCL 11/7

The long-term effects of the orbital debris and micrometeoroid environments on materials that are current candidates for use on space vehicles are discussed. In addition, the limits of laboratory testing to determine these effects are defined and the need for space-based data is delineated. The impact effects discussed are divided into primary and secondary surfaces. Primary surfaces are those that are subject to erosion, pitting, the degradation and delamination of optical coatings, perforation of atomic oxygen erosion barriers, vapor coating of optics and the production of secondary ejecta particles. Secondary surfaces are those that are affected by the result of the perforation of primary surfaces, for example, vapor deposition on electronic components and other sensitive equipment, and the production of fragments with damage potential to internal pressurized elements. The material properties and applications that are required to prevent or lessen the effects described, are defined. Author

**N89-23543\*** National Aeronautics and Space Administration.  
Lyndon B. Johnson Space Center, Houston, TX.  
**ORBITAL DEBRIS ENVIRONMENT AND DATA**

### REQUIREMENTS

DONALD J. KESSLER In NASA, Langley Research Center,  
NASA/SOIO Space Environmental Effects on Materials Workshop,  
Part 1 p 281-299 May 1989

Avail: NTIS HC A16/MF A02 CSCL 03/2

Orbital debris is already a major design consideration for Space Station Freedom and is becoming important to the design of unmanned spacecraft. Mathematical models predict the environment will increase with time. The amount it increases is dependent on future operations in space, and how these operations are conducted. Therefore, it is important to understand the sources of debris and which operations will minimize debris generation. This requires that debris be monitored. Currently, NASA plans to have an operational capability to monitor 1 cm debris at 500 km by 1991. However, there are currently no plans to monitor the environment of smaller debris which will be important to future spacecraft design. Author

**N89-23544\*** National Aeronautics and Space Administration.  
Lyndon B. Johnson Space Center, Houston, TX.

### MICROPARTICLE IMPACTS IN SPACE: RESULTS FROM SOLAR MAX AND SHUTTLE WITNESS PLATE INSPECTIONS

DAVID S. MCKAY In NASA, Langley Research Center,  
NASA/SOIO Space Environmental Effects on Materials Workshop,  
Part 1 p 301-327 May 1989

Avail: NTIS HC A16/MF A02 CSCL 11/7

The Solar Maximum Satellite developed electronic problems after operating successfully in space for several years. Astronauts on Space Shuttle mission STS-41C retrieved the satellite into the orbiter cargo bay, replaced defective components, and re-deployed the repaired satellite into orbit. The defective components were returned to Earth for study. The space-exposed surfaces were examined. The approach and objectives were to: document morphology of impact; find and analyze projectile residue; classify impact by origin; determine flux distribution; and determine implications for space exposure. The purpose of the shuttle witness plate experiment was to detect impacts from PAM D2 solid rocket motor; determine flux and size distribution of particles; and determine abrasion effects on various conditions. Results are given for aluminum surfaces, copper surfaces, stainless steel surfaces, Inconel surfaces, and quartz glass surfaces. Author

**N89-23545\*** Jet Propulsion Lab., California Inst. of Tech.,  
Pasadena.

### EFFECTS OF THE CONTAMINATION ENVIRONMENT ON SURFACES AND MATERIALS

CARL R. MAAG In NASA, Langley Research Center, NASA/SOIO  
Space Environmental Effects on Materials Workshop, Part 1 p  
353-364 May 1989

Avail: NTIS HC A16/MF A02 CSCL 11/7

In addition to the issues that have always existed, demands are being placed on space systems for increased contamination prevention/control. Optical surveillance sensors are required to detect low radiance targets. This increases the need for very low scatter surfaces in the optical system. Particulate contamination levels typically experienced in today's working environments/habits will most likely compromise these sensors. Contamination (molecular and particulate) can also affect the survivability of space sensors in both the natural and hostile space environments. The effects of di-octyl phthalate (DOP) on sensors are discussed. Author

**N89-23546\*** Aerospace Corp., Los Angeles, CA.

### THE SPACE PARTICLE ENVIRONMENT

ALFRED L. VAMPOLA In NASA, Langley Research Center,  
NASA/SOIO Space Environmental Effects on Materials Workshop,  
Part 2 p 357-382 May 1989

Avail: NTIS HC A12/MF A02 CSCL 03/2

The energetic charged particle environment in the Earth's magnetosphere was studied. An overview is provided of trapped particle morphology, the geometry of the trapping regions, the radiation environmental models, the current status of these models, and future modeling requirements. Author

**N89-23548\*** Aerospace Corp., El Segundo, CA. Space Sciences  
Lab.

### EFFECTS OF SPACE RADIATION ON ELECTRONIC MICROCIRCUITS

W. A. KOLASINSKI In NASA, Langley Research Center,  
NASA/SOIO Space Environmental Effects on Materials Workshop,  
Part 2 p 383-392 May 1989

Avail: NTIS HC A12/MF A02 CSCL 09/3

The single event effects or phenomena (SEP), which so far have been observed as events falling on one or another of the SE classes: Single Event Upset (SEU), Single Event Latchup (SEL) and Single Event Burnout (SEB), are examined. Single event upset is defined as a lasting, reversible change in the state of a multistable (usually bistable) electronic circuit such as a flip-flop or latch. In a computer memory, SEUs manifest themselves as unexplained bit flips. Since latchup is in general caused by a single event of short duration, the single event part of the SEL term is superfluous. Nevertheless, it is used customarily to differentiate latchup due to a single heavy charged particle striking a sensitive cell from more ordinary kinds of latchup. Single event burnout (SEB) refers usually to total instantaneous failure of a power FET when struck by a single particle, with the device shorting out the power supply. An unforeseen failure of these kinds can be catastrophic to a space mission, and the possibilities are discussed. Author

**N89-23551\*** National Aeronautics and Space Administration.  
Langley Research Center, Hampton, VA.

### ULTRAVIOLET RADIATION EFFECTS

WAYNE S. SLEMP In NASA/SOIO Space Environmental  
Effects on Materials Workshop, Part 2 p 425-446 May 1989

Avail: NTIS HC A12/MF A02 CSCL 11/7

Solar ultraviolet testing was not developed which will provide highly accelerated (20 to 50X) exposures that correlate to flight test data. Additional studies are required to develop an exposure methodology which will assure that accelerated testing can be used for qualification of materials and coatings for long duration space flight. Some conclusions are listed: Solar UV radiation is present in all orbital environments; Solar UV does not change in flux with orbital altitude; UV radiation can degrade most coatings and polymeric films; Laboratory UV simulation methodology is needed for accelerated testing to 20 UV solar constants; Simulation of extreme UV (below 200 nm) is needed to evaluate requirements for EUV in solar simulation. Author

**N89-23553\*** Air Force Geophysics Lab., Hanscom AFB, MA.  
Space Physics Div.

### DIELECTRICS FOR LONG TERM SPACE EXPOSURE AND SPACECRAFT CHARGING: A BRIEFING

A. R. FREDERICKSON In NASA, Langley Research Center,



NASA/SDIO Space Environmental Effects on Materials Workshop, Part 2 p 473-494 May 1989

Avail: NTIS HC A12/MF A02 CSCL 22/2

Charging of dielectrics is a bulk, not a surface property. Radiation driven charge stops within the bulk and is not quickly conducted to the surface. Very large electric fields develop in the bulk due to this stopped charge. At space radiation levels, it typically requires hours or days for the internal electric fields to reach steady state. The resulting electric fields are large enough to produce electrical failure within the insulator. This type failure is thought to produce nearly all electric discharge anomalies. Radiation also induces bond breakage, creates reactive radicals, displaces atoms and, in general, severely changes the chemistry of the solid state material. Electric fields can alter this process by reacting with charged species, driving them through the solid. Irradiated polymers often lose as much as a percent of their mass, or more, at exposures typical in space. Very different aging or contaminant emission can be induced by the stopped charge electric fields. These radiation effects are detailed. Author

**N89-23554\*** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

#### AN OVERVIEW OF CHARGING ENVIRONMENTS

S. B. GABRIEL and H. B. GARRETT In NASA, Langley Research Center, NASA/SDIO Space Environmental Effects on Materials Workshop, Part 2 p 495-509 May 1989

Avail: NTIS HC A12/MF A02 CSCL 11/7

A brief synopsis of the natural environments that play a role in spacecraft charging is presented. Environments that cause both surface and internal charging are discussed along with the mechanisms involved. The geosynchronous and low altitude regions of the Earth's magnetosphere/ionosphere are considered and simple descriptions of each environment presented. As material properties are critical to the charging process, definition of material properties important to charging, which can be affected by the environment, are also described. Several space experiments are proposed that would help fill the gaps in the knowledge of the performance of materials in a charging environment. Author

**N89-23555\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

#### SURFACE PHENOMENA IN PLASMA ENVIRONMENTS

C. K. PURVIS and D. C. FERGUSON In NASA, Langley Research Center, NASA/SDIO Space Environmental Effects on Materials Workshop, Part 2 p 511-534 May 1989

Avail: NTIS HC A12/MF A02 CSCL 20/9

Plasma interactions and their effects on materials depend on a number of factors, including the pre-existing environment, the properties of surface materials and the characteristics of the system. An additional dimension is the question of mission: some payloads may be much more sensitive to plasma interactions than others. As an example, a payload whose objective is to measure the ambient environment will be more sensitive to any effects than will a power system. Material specific effects include charging and its associated effects, which can result in short- and long-term damage. Selection of materials for a particular application requires consideration of all factors and assessment of effects due to all causes. Proper selection and suitability determination requires analysis to identify the actual environment combined with testing under exposure to single and combined environment factors. Author

**N89-23556\*** TRW Space Technology Labs., Redondo Beach, CA. System Integration Lab.

#### INFLUENCE OF CHARGING ENVIRONMENTS ON SPACECRAFT MATERIALS AND SYSTEM PERFORMANCE

N. JOHN STEVENS In NASA, Langley Research Center, NASA/SDIO Space Environmental Effects on Materials Workshop, Part 2 p 535-542 May 1989

Avail: NTIS HC A12/MF A02 CSCL 22/2

An overview is presented of potential interactions that can occur on spacecraft operating in space environments. These interactions are discussed in detail. The environment acts on spacecraft in

such a way that charging of exterior surfaces occurs. The consequences from this charging then affect system operational performance. Hence, it is the coupling of this exterior charging to system performance that is of concern here. These interactions were first discovered in the spacecraft charging phenomena in which the geomagnetic substorms charged external surfaces to a level that discharges occurred. As a result of the discharge, electronic systems either changed logic state (anomalous switching) or failed. These interactions can occur in all orbits. The type associated with geosynchronous orbits is called passive since the environment provides the charging mechanism. This type can also occur in polar orbits due to auroral charging environments. In low Earth orbits, the thermal plasma alleviates charging environment concerns, but system operations can induce similar effects. Author

**N89-23558\*** National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, TX.

#### MICROMETEORITIDS AND DEBRIS

ANDREW POTTER In NASA, Langley Research Center, NASA/SDIO Space Environmental Effects on Materials Workshop, Part 2 p 553-557 May 1989

Avail: NTIS HC A12/MF A02 CSCL 03/2

The materials with vulnerability to micrometeoroids and space debris are discussed. It is concluded that all materials are vulnerable to hypervelocity impacts and that the importance of these impacts depends on the function of material. It is also concluded that low earth orbits are the most significant region relative to orbital debris. The consequences of aerospace environment effects are discussed. E.R.

**N89-23559\*** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

#### CONTAMINATION

CARL R. MAAG In NASA, Langley Research Center, NASA/SDIO Space Environmental Effects on Materials Workshop, Part 2 p 559-563 May 1989

Avail: NTIS HC A12/MF A02 CSCL 11/7

Contamination of spacecraft in the aerospace environment is examined. The optical systems, thermal control systems and solar power systems were deemed to be most vulnerable to particle damage. It was decided that all orbits should be considered. Specific issues concern whether there are changes in transmittance of optics and the radiative properties of protective coatings. E.R.

**N89-23560\*** Aerospace Corp., Los Angeles, CA.

#### TRAPPED RADIATION

ALFRED L. VAMPOLA and WAYNE K. STUCKEY In NASA, Langley Research Center, NASA/SDIO Space Environmental Effects on Materials Workshop, Part 2 p 565-568 May 1989

Avail: NTIS HC A12/MF A02 CSCL 11/7

The vulnerability of spacecraft materials and components to trapped radiation in aerospace environment is considered along with which orbits the radiation effects are most likely to occur. It seems that the effects on organic polymers are embrittlement, change of modulus and coefficient of expansion; on optics the effects are discoloration and distortion. The effects on integrated circuits are also listed. E.R.

**N89-23561\*** National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, MD.

#### TRAPPED PARTICLE FLUX MODELS AT NSSDC/WDC-A-R/S

D. BLITZ, D. M. SAWYER, and J. H. KING In NASA, Langley Research Center, NASA/SDIO Space Environmental Effects on Materials Workshop, Part 2 p 569-572 May 1989

Avail: NTIS HC A12/MF A02 CSCL 11/7

The data needed in the future for trapped particle modeling are summarized. A short summary of past and future modeling activities and a list of satellite data that have not yet been considered in the modeling efforts is included. Author

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**N89-23562\*** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

### SOLAR RADIATION

WAYNE S. SLEMP *In its NASA/SDIO Space Environmental Effects on Materials Workshop, Part 2 p 573-575 May 1989*  
Avail: NTIS HC A12/MF A02 CSCL 03/2

The effects of solar radiation in aerospace environments on aerospace systems are examined. It was concluded that most materials degrade to solar radiation. The information available on short term effects on materials provides a limited data base. Flight data on coating degradation seems to be confused by contamination. Other conclusions of data examination are listed.

E.R.

**N89-23563\*** TRW Space Technology Labs., Redondo Beach, CA.

### SPACECRAFT CHARGING

N. JOHN STEVENS *In NASA, Langley Research Center, NASA/SDIO Space Environmental Effects on Materials Workshop, Part 2 p 577-584 May 1989*  
Avail: NTIS HC A12/MF A02 CSCL 22/2

The effects of spacecraft charging on spacecraft materials are studied. Spacecraft charging interactions seem to couple environment to system performance through materials. Technology is still developing concerning both environment-driven and operating system-driven interactions. The meeting addressed environment but lacked specific mission requirements, as a result system definition are needed to prioritize interactions.

E.R.

**N89-23564\*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

### WORKING GROUP WRITTEN PRESENTATION: ATOMIC OXYGEN

LUBERT J. LEGER and JAMES T. VISENTINE *In NASA, Langley Research Center, NASA/SDIO Space Environmental Effects on Materials Workshop, Part 2 p 587-588 May 1989*  
Avail: NTIS HC A12/MF A02 CSCL 11/7

Earlier Shuttle flight experiments have shown NASA and SDIO spacecraft designed for operation in low-Earth orbit (LEO) must take into consideration the highly oxidative characteristics of the ambient flight environment. Materials most adversely affected by atomic oxygen interactions include organic films, advanced (carbon-based) composites, thermal control coatings, organic-based paints, optical coatings, and thermal control blankets commonly used in spacecraft applications. Earlier results of NASA flight experiments have shown prolonged exposure of sensitive spacecraft materials to the LEO environment will result in degraded systems performance or, more importantly, lead to requirements for excessive on-orbit maintenance, with both conditions contributing significantly to increased mission costs and reduced mission objectives. Flight data obtained from previous Space Shuttle missions and results of the Solar Max recovery mission are limited in terms of atomic oxygen exposure and accuracy of fluence estimates. The results of laboratory studies to investigate the long-term (15 to 30 yrs) effects of AO exposure on spacecraft surfaces are only recently available, and qualitative correlations of laboratory results with flight results have been obtained for only a limited number of materials. The working group recommended the most promising ground-based laboratories now under development be made operational as soon as possible to study the full-life effects of atomic oxygen exposure on spacecraft systems.

Author

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### WORKING GROUP WRITTEN PRESENTATION: METEOROID/ORBITAL DEBRIS EFFECTS ON MATERIALS

ANDREW POTTER *In NASA, Langley Research Center, NASA/SDIO Space Environmental Effects on Materials Workshop, Part 2 p 589-594 May 1989*  
Avail: NTIS HC A12/MF A02 CSCL 11/7

Low earth orbit (LEO) is the most significant region relative to orbital debris, since the flux of orbital debris peaks in the region

from 800 to 1000 kilometers, and the relative velocities of objects in LEO are about 10 kilometers per second. The flux and relative velocities of objects in geosynchronous orbit (GEO) are small, so that debris is not considered to be a problem in GEO. The meteoroid environment is independent of orbit or altitude, so that its effects are the same in LEO and GEO. The effects of orbital debris and meteoroid impacts can be divided into two broad regions: (1) Erosion and pitting; Small particles (less than 100 microns) are very numerous. Impacts from these generally do not lead to penetration of surfaces, but cause pitting and erosion. The Solar Max surfaces were peppered with thousands of tiny impact pits. (2) Catastrophic impacts; Large debris particles are few in number relative to small debris, so that the probability of an impact is low. However, the effects of an impact of a large particle at 10 kilometers per second are devastating. These effects are examined.

Author

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### WORKING GROUP WRITTEN PRESENTATION: TRAPPED RADIATION EFFECTS

ALFRED L. VAMPOLA, WAYNE K. STUCKEY, D. COULTER, E. J. FRIEBELE, K. J. HAND, D. A. HARDY, P. HIGBY, W. A. KOLASINSKI, R. T. SANTORO, and STEPHEN S. TOMPKINS (National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.) *In its NASA/SDIO Space Environmental Effects on Materials Workshop, Part 2 p 597-605 May 1989*  
Avail: NTIS HC A12/MF A02 CSCL 11/7

The results of the Trapped Radiation Effects Panel for the Space Environmental Effects on Materials Workshop are presented. The needs of the space community for new data regarding effects of the space environment on materials, including electronics are listed. A series of questions asked of each of the panels at the workshop are addressed. Areas of research which should be pursued to satisfy the requirements for better knowledge of the environment and better understanding of the effects of the energetic charged particle environment on new materials and advanced electronics technology are suggested.

Author

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### WORKING GROUP WRITTEN PRESENTATION: SOLAR RADIATION

WAYNE S. SLEMP *In its NASA/SDIO Space Environmental Effects on Materials Workshop, Part 2 p 607-608 May 1989*  
Avail: NTIS HC A12/MF A02 CSCL 11/7

The members of the Solar Radiation Working Group arrived at two major solar radiation technology needs: (1) generation of a long term flight data base; and (2) development of a standardized UV testing methodology. The flight data base should include 1 to 5 year exposure of optical filters, windows, thermal control coatings, hardened coatings, polymeric films, and structural composites. The UV flux and wavelength distribution, as well as particulate radiation flux and energy, should be measured during this flight exposure. A standard testing methodology is needed to establish techniques for highly accelerated UV exposure which will correlate well with flight test data. Currently, UV can only be accelerated to about 3 solar constants and can correlate well with flight exposure data. With space missions to 30 years, acceleration rates of 30 to 100X are needed for efficient laboratory testing.

Author

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### WORKING GROUP WRITTEN PRESENTATION: SPACECRAFT CHARGING

N. JOHN STEVENS *In NASA, Langley Research Center, NASA/SDIO Space Environmental Effects on Materials Workshop, Part 2 p 609-612 May 1989*  
Avail: NTIS HC A12/MF A02 CSCL 22/2

A brief listing of the concerns of the working group on spacecraft charging is presented. Brief conclusions for each concern is also given.

E.R.

**N89-24230#** European Space Agency, Paris (France). ESA Debris Working Group.

**SPACE DEBRIS: A REPORT FROM THE ESA DEBRIS WORKING GROUP**

Nov. 1988 74 p

(ESA-SP-1109; ISSN-079-6566; ETN-89-94237) Copyright Avail: NTIS HC A04/MF A01; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 30 Dutch guilders

Available data on space debris; the natural environment; the situation in low Earth orbits; the situation in geostationary orbit; risks on the ground posed by reentering space objects; influence of space debris on ground-based and spaceborne astronomy; preventive measures; and legal aspects are reviewed. ESA

**N89-24408#** Lawrence Livermore National Lab., CA. **CAPABILITIES AND SOME APPLICATIONS OF THE LLNL 100-KV ELECTRIC GUN**

J. E. OSHER, G. R. GATHERS, H. H. CHAU, and R. C. WEINGART Jun. 1989 11 p Presented at the 3rd International Symposium on Behavior of Media Under High Dynamic Pressures, La Grande Motte, France, 5-9 Jun. 1989 (Contract W-7405-ENG-48)

(DE89-006747; UCRL-98804; CONF-890661-4) Avail: NTIS HC A03/MF A01

The LLNL 100-kV electric gun is an experimental device for launching thin flyer plates at velocities as high as 20 km/s to study impact damage and shock-wave physics. The hypervelocity impact studies reported here include a damage study of spalling damage in aluminum, a study of one-dimensional shock-wave attenuation in materials, use of the well-characterized one-dimensional shock waves for equation-of-state measurements in various materials, and use of thin flyer plates at velocities up to 18 km/s to produce reverse ballistic impact on target objects such as rods to measure damage and fragmentation. Our studies include both experimental results and correlation with numerical calculations using a code such as DYNA2D. DOE

**N89-24734#** Aerospace Corp., Los Angeles, CA. **CONTAMINATION EFFECTS OF GPS NAVSTAR SOLAR ARRAY PERFORMANCE**

DEAN C. MARYIN and WARREN C. HWANG In NASA, Lewis Research Center, Space Photovoltaic Research and Technology, 1988. High Efficiency, Space Environment, and Array Technology p 301-305 Apr. 1989

Avail: NTIS HC A16/MF A03 CSCL 10/1

The solar arrays on Navstars 1 to 6 have been limiting the electrical power capabilities in the extended life (beyond the 5 year design life). The departure from predicted performance consists of an extra 2.5 percent per year degradation beyond the radiation model estimates. This degradation is unusual in showing a linear rather than exponential decay with time. The performance of the arrays on these satellites has been examined in order to predict future behavior and to make refined projections on the Navstar 7 to 11 solar arrays. Evidence obtained from flight experiments on Navstar 5 and 6, and from laboratory experiments, suggests that contamination of the solar arrays while on orbit may be responsible. The evidence for photo-induced contamination of spacecraft surfaces is presented, and the effect on solar array output in the case of the GPS satellites is shown to be consistent with the observed anomalies. Author

**N89-25254#** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**ADVANCED APS IMPACTS ON VEHICLE PAYLOADS**

STEVEN J. SCHNEIDER and BRIAN D. REED 1989 14 p Presented at the JANNAF Propulsion Meeting, Cleveland, OH, 23-25 May 1989

(NASA-TM-102068; E-4731; NAS 1.15:102068) Avail: NTIS HC A03/MF A01 CSCL 22/2

Advanced auxiliary propulsion system (APS) technology has the potential to both increase the payload capability of earth-to-orbit (ETO) vehicles by reducing APS propellant mass, and simplify ground operations and logistics by reducing the number

of fluids on the vehicle and eliminating toxic, corrosive propellants. The impact of integrated cryogenic APS on vehicle payloads is addressed. In this system, launch propulsion system residuals are scavenged from integral launch propulsion tanks for use in the APS. Sufficient propellant is preloaded into the APS to return to earth with margin and noncomplete scavenging assumed. No propellant conditioning is required by the APS, but ambient heat soak is accommodated. High temperature rocket materials enable the use of the unconditioned hydrogen/oxygen in the APS and are estimated to give APS rockets specific impulse of up to about 444 sec. The payload benefits are quantified and compared with an updated monomethylhydrazine/nitrogen tetroxide system in a conservative fashion, by assuming a 25.5 percent weight growth for the hydrogen/oxygen system and a 0 percent weight growth for the updated system. The combination of scavenging and high performance gives payload impacts which are highly mission specific. A payload benefit of 861 kg (1898 lbm) was estimated for a Space Station Freedom rendezvous mission and 2099 kg (4626 lbm) for a sortie mission, with payload impacts varying with the amount of launch propulsion residual propellants. Missions without liquid propellant scavenging were estimated to have payload penalties, however, operational benefits were still possible.

Author

**N89-25818#** National Aeronautics and Space Administration, Washington, DC.

**SOLAR PHYSICS IN THE SPACE AGE**

1989 53 p

(NASA-NP-106; NAS 1.83:106) Avail: NTIS HC A04/MF A01 CSCL 03/2

A concise and brief review is given of the solar physics' domain, and how its study has been affected by NASA Space programs which have enabled space based observations. The observations have greatly increased the knowledge of solar physics by proving some theories and challenging others. Many questions remain unanswered. To exploit coming opportunities like the Space Station, solar physics must continue its advances in instrument development, observational techniques, and basic theory. Even with the Advance Solar Observatory, other space based observation will still be required for the sure to be ensuing questions. E.R.

**N89-26025#** Arizona Univ., Tucson. **DESIGN OF A FLEXURE MOUNT FOR OPTICS IN DYNAMIC AND CRYOGENIC ENVIRONMENTS**

LLOYD WAYNE POLLARD Feb. 1989 135 p

(Contract N002-426)

(NASA-OR-177495; NAS 1.26:177495) Avail: NTIS HC A07/MF A01 CSCL 14/2

The design of a flexure mount for a mirror operating in a cryogenic environment is presented. This structure represents a design effort recently submitted to NASA Ames for the support of the primary mirror of the Space Infrared Telescope Facility (SIRTF). The support structure must passively accommodate the differential thermal contraction between the glass mirror and the aluminum structure of the telescope during cryogenic cooldown. Further, it must support the one meter diameter, 116 kilogram (258 pound) primary mirror during a severe launch to orbit without exceeding the micro-yield of the material anywhere in the flexure mount. Procedures used to establish the maximum allowable radial stiffness of the flexural mount, based on the finite element program NASTRAN and the optical program FRINGE, are discussed. Early design concepts were evaluated using a parametric design program, and the development of that program is presented. Dynamic loading analyses performed with NASTRAN are discussed. Methods of combining modal responses resulting from a displacement response spectrum analysis are discussed, and a combination scheme called MRSS, modified root of sum of squares, is presented. Modal combination schemes using MRSS, SRSS, and ABS are compared to the results of the modal frequency response analysis performed with NASTRAN. Author



**N89-26035\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

**EFFECT OF MICROMETEOROID AND SPACE DEBRIS IMPACTS ON THE SPACE STATION FREEDOM SOLAR ARRAY SURFACES**

HENRY K. NAHRA 1989 12 p Presented at the 1989 Spring Meeting of the Materials Research Society, San Diego, CA, 24-29 Apr. 1989

(NASA-TM-102287; E-4955; NAS 1.15:102287) Avail: NTIS HC A03/MF A01 CSCL 22/2

Both solar and antisolar surfaces of the Space Station Freedom solar arrays are vulnerable to micrometeoroid and space debris impacts. Impacts on the solar surface result in damage to the active area of the solar cell and a corresponding reduction in generated power. Impacts on the antisolar surface could result in damage to the circuit which interconnects the cells which in turn may produce open circuit strings or panels. An evaluation is presented of the power degradation resulting from the impacts of micrometeoroid and space debris on the solar surface of the array blanket. Moreover, given a particle diameter that could damage the circuit interconnecting the cells, the probability of an open circuit panel is computed, along with the probability that the solar array blanket will meet the power requirement over the design lifetime.

Author

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**PLASMA DIAGNOSTICS PACKAGE. VOLUME 2: SPACELAB 2 SECTION. PART B: THEMIS PROJECTS Final Science Report**

JOLENE S. PICKETT, comp., L. A. FRANK, comp., and W. S. KURTH, comp. Jun. 1988 725 p

(Contract NAS8-32807) (NASA-CR-183699; NAS 1.26:183699) Avail: NTIS HC A99/MF E03 CSCL 20/9

This volume (2), which consists of two parts (A and B), of the Plasma Diagnostics Package (PDP) Final Science Report contains a summary of all of the data reduction and scientific analyses which were performed using PDP data obtained on STS-51F as a part of the Spacelab 2 (SL-2) payload. This work was performed during the period of launch, July 29, 1985, through June 30, 1986. During this period the primary data reduction effort consisted of processing summary plots of the data received by 12 of the 14 instruments located on the PDP and submitting these data to the National Space Science Data Center (NSSDC). Three Master's and three Ph.D. theses were written using PDP instrumentation data. These theses are listed in Volume 2, Part B.

K.C.D.

**N89-26721\*** Iowa Univ., Iowa City. Dept. of Physics and Astronomy.

**PLASMA DIAGNOSTICS PACKAGE. VOLUME 1: OSS-1 SECTION Final Science Report**

JOLENE S. PICKETT, comp., L. A. FRANK, comp., and W. S. KURTH, comp. Jun. 1988 234 p

(Contract NAS8-32807) (NASA-CR-183697; NAS 1.26:183697) Avail: NTIS HC A11/MF A02 CSCL 20/9

This volume (1) of the Plasma Diagnostics Package (PDP) final science report contains a summary of all of the data reduction and scientific analyses which were performed using PDP data obtained on STS-3 as a part of the Office of Space Science first payload (OSS-1). This work was performed during the period of launch, March 22, 1982, through June 30, 1983. During this period the primary data reduction effort consisted of processing summary plots of the data received by the 14 instruments located on the PDP and submitting these data to the National Space Science Data Center (NSSDC). The scientific analyses during the performance period consisted of general studies which incorporated the results of several of the PDP's instruments, detailed studies which concentrated on data from only one or two of the instruments, and joint studies of beam-plasma interactions with the OSS-1 Fast Pulse Electron Generator (FPEG) of the Vehicle Charging and Potential Investigation (VCAPI). Internal reports, published papers and oral presentations which involve PDP/OSS-1 data are listed

in Sections 3 and 4. A PDP/OSS-1 scientific results meeting was held at the University of Iowa on April 19-20, 1983. This meeting was attended by most of the PDP and VCAPI investigators and provided a forum for discussing and comparing the various results, particularly with regard to the shuttle orbiter environment. One of the most important functional objectives of the PDP on OSS-1 was to characterize the orbiter environment.

K.C.D.

**N89-26722\*** Iowa Univ., Iowa City. Dept. of Physics and Astronomy.

**PLASMA DIAGNOSTICS PACKAGE. VOLUME 2: SPACELAB 2 SECTION. PART A Final Science Report**

JOLENE S. PICKETT, comp., L. A. FRANK, comp., and W. S. KURTH, comp. Jun. 1988 488 p

(Contract NAS8-32807) (NASA-CR-183698; NAS 1.26:183698) Avail: NTIS HC A21/MF A03 CSCL 20/9

This volume (2), which consists of two parts (A and B), of the Plasma Diagnostics Package (PDP) Final Science Report contains a summary of all of the data reduction and scientific analyses which were performed using PDP data obtained on STS-51F as a part of the Spacelab 2 (SL-2) payload. This work was performed during the period of launch, July 29, 1985, through June 30, 1986. During this period the primary data reduction effort consisted of processing summary plots of the data received by 12 of the 14 instruments located on the PDP and submitting these data to the National Space Science Data Center (NSSDC). The scientific analyses during the performance period consisted of follow-up studies of shuttle orbiter environment and orbiter/ionosphere interactions and various plasma particle and wave studies which dealt with data taken when the PDP was on the Remote Manipulator System (RMS) arm and when the PDP was in free flight. Of particular interest during the RMS operations and free flight were the orbiter wake studies and joint studies of beam/plasma interactions with the SL-2 Fast Pulse Electron Generator (FPEG) of the Vehicle Charging and Potential Investigation (VCAPI). Internal reports, published papers and presentations which involve PDP/SL-2 data are listed in Sections 3 and 4. A PDP/SL-2 scientific results meeting was held at the University of Iowa on June 10, 1986. This meeting was attended by most of the PDP and VCAPI investigators and provided a forum for discussing and comparing the various results, particularly with regard to the PDP free flight.

K.C.D.

**N89-27089# Sandia National Labs., Albuquerque, NM. TOTAL-DOSE HARDNESS ASSURANCE FOR SPACE APPLICATIONS OF COMMERCIAL CMOS DEVICES**

D. M. FLEETWOOD, P. S. WINOKUR, and R. L. PEASE (Mission Research Corp., Albuquerque, NM.) 1989 5 p Presented at the 26th Annual Conference on Nuclear and Space Radiation Effects, Marco Island, FL, 24 Jul. 1989

(Contract DE-AC04-76DP-00788) (DE89-006765; SAND-89-0181C; CONF-890723-2) Avail: NTIS HC A01/MF A01

Lot acceptance tests are evaluated for nonhardened CMOS devices for low total-dose space applications. Examples are presented for cases in which gate- or field-oxide leakage dominates device response.

DOE

**N89-27287# Aerospace Corp., El Segundo, CA. Space Sciences Lab.**

**THE SPACE PARTICLE ENVIRONMENT**

ALFRED L. VAMPOLA 28 Mar. 1989 32 p Previously announced as N89-23548

(Contract F04701-85-C-0086) (AD-A207547; TR-0086(3940-05)-8; SO-TR-89-30) Avail: NTIS HC A03/MF A01 CSCL 04/1

This report is a tutorial covering the energetic charged particle environment in the earth's magnetosphere. It provides an overview of trapped particle morphology, the geometry of the trapping regions, the radiation environmental models, the current status of these models, and future modeling requirements.

GRA

**N89-27476#** Oak Ridge National Lab., TN. Engineering Physics and Mathematics Div.

**SHIELD OPTIMIZATION PROGRAM. PART 1: EXECUTIVE SUMMARY**

R. T. SANTORO and T. A. GABRIEL. Jun. 1989. 48 p.  
(Contract DE-AC05-84OR-21400)  
(DE89-013335; ORNL/TM-11143-PT-1) Avail: NTIS HC A03/MF A01

Detailed studies have been completed to estimate the radiation-induced damage in sensitive electronic components carried on a space-based interceptor weapons platform. The architecture of the interceptor was devised to be as realistic as possible. The analyses were completed for natural (Van Allen belt protons and electrons at an orbital altitude of 500 km) and man-made (nuclear weapons: neutrons, gamma-rays, X-rays, and pumped electron belts) radiation expected to be encountered by a SDI platform. Studies have also been completed to determine the hydrodynamic responses of beryllium mirror surfaces to mono-energetic X-rays (1 and 2 keV). This work included the effects of impurities which are introduced into the surface during machining. Finally, a comparison of the HULL and PUFF-TFT codes are presented which includes the thermo-mechanical response of an Al slab to 5 keV black body radiation. DOE

**N89-27607#** National Oceanic and Atmospheric Administration, Boulder, CO. Space Environment Lab.

**SPACE ENVIRONMENT LABORATORY Annual Report, FY 1988, 1 Oct. 1987 - 30 Sep. 1988**

Jan. 1989. 50 p.  
(PB89-159602) Avail: NTIS HC A03/MF A01 CSCL 03/2

Topics covered include: space environment data collection services; solar flare forecasting and analysis; geomagnetic services development; research (ionospheric radio, sudden ionospheric disturbances, atmospheric ionospheric magnetospheric interactions, magnetospheric physics, interplanetary physics, solar physics, and solar X-ray physics); and development (space environment data system, operational satellite instrumentation, workstation and expert systems, object oriented programming, wide-area networking, and interplanetary scintillation observations). A listing of personnel, publications and talks is also presented. K.C.D.

**N89-27720#** Massachusetts Inst. of Tech., Cambridge.  
**THE INTERACTION BETWEEN A POSITIVELY BIASED CONDUCTOR ON A HIGH VOLTAGE SOLAR ARRAY AND A PLASMA**

DANIEL E. HASTINGS. In DGLR, DGLR/AIAA/JSASS 20th International Electric Propulsion Conference: Proceedings p 115-120. 1988.

Avail: NTIS HC A99/MF E03

The physics of a positively biased conductor surrounded by dielectrics in contact with plasma is investigated. It is shown that due to the presence of secondary emission from the surrounding dielectrics the voltage of the surfaces near the conductor can be bistable. One of the bistable solutions always has very low secondary emission while the other has high secondary emission. The secondary current emitted from the neighboring dielectrics is collected by the conductor. When the voltage on the dielectric undergoes a transition from one bistable solution to another this is seen as a concomitant increase in the current collected to the conductor. A theoretical treatment for a conductor surrounded by dielectrics such as silicon dioxide is presented. The theory is applied to explain the snapover effect. The snapover effect is observed on high voltage solar arrays which involve the use of highly biased surfaces in contact with the space environment. When such surfaces are positively biased the current undergoes an anomalous increase at a critical voltage. ESA

**N89-27794#** Japan Atomic Energy Research Inst., Tokyo.  
**IRRADIATION EFFECTS ON RESISTANCE OF THERMAL IMPACT OF COMPOSITE USED IN SPACE**

TSUNEO SASUGA, SIGENORI EGUSA, AKIRA UDAGAWA, TADAO SEGUCHI, NAOKYU TAMURA, TAKAYUKI KAMIYAMA,

NORIKI SUGAHARA, TAKESHI NAKAO, YUJIRO YOSHIDA, and TOSIO SAKAKIBARA. Nov. 1988. 34 p. In JAPANESE; ENGLISH summary.

(DE89-778062; JAERI-M-88-238) Avail: NTIS (US Sales Only) HC A03/MF A01

Electron irradiation effects on mechanical properties at low(-100 C), high(100 C) and room temperatures, and on the cyclic thermal impact from high(100 C) to low(-90 C) were studied for IM-6/R376 composite in which modified TGDOM-DOS matrix was reinforced by a high strength inter mediate modules carbon fiber(IM-6) and T-300/3601 composite which was composed of non-modified TGDOM-DOS matrix and a high strength carbon fiber(T-300), and then adaptability of these materials to environments of space was evaluated. LISS was decreased by irradiation over 10 MGy in IM-6/R376 composite and 20 MGy in T-300/3601 composite, but the tensile and compression strength at low, high and room temperatures were scarcely affected by irradiation up to 10 MGy. When unirradiated T-300/3601 composite was subjected by thermal impact, many microcracks were produced and the compression strength decrease to 90 percent of the initial value but the production on microcrack and decreasing in the compression strength by thermal impact tended to become less in the irradiated specimen. On the other hand, in the unirradiated IM-6/R376 composite production of microcrack was not observed by thermal impact and decrease in strength was less but microcracks were produced and the strength decrease by thermal impact after irradiation. In the case of irradiation after thermal impact, radiation effects were not observed. It was concluded from these results that both the composites have enough resistance against environmental radiation in space, and IM-6/R376 composite is excellent more than T-300/3601 composite in consideration of resistance for thermal impact. DOE

**N89-27950#** Southwest Research Inst., San Antonio, TX.  
**A STUDY OF SPACECRAFT ELECTROMAGNETIC CONTAMINATION OF ARTIFICIAL ELECTRON BEAMS Final Report, 1 Aug. 1987 - 31 Sep. 1988**

C. S. LIN. 31 Dec. 1988. 54 p.  
(Contract F19628-85-K-0004)  
(AD-A209954; GL-TR-89-0121) Avail: NTIS HC A04/MF A01 CSCL 20/3

The numerical code developed for solving the dispersion equation of the electromagnetic dispersion equation for a finite radius electron beam in a neutralizing background is documented. Derivation of the dispersion equation from the fluid equation and Maxwell's equations is described. To study electromagnetic radiation induced by electron beam injection from the Space Shuttle, the numerical code is applied to solve for the instability growth rates for the beam and whistler modes. The numerical solutions indicate that a finite radius electron beam injected into the ionosphere with the beam energy around 1 keV and current about 100 mA can drive the beam and whistler modes unstable. The results can explain the whistler waves radiated from the keV electron beam injected from Spacelab 2. GFA

**N89-28462#** National Oceanic and Atmospheric Administration, Boulder, CO.

**SOLAR PROTON EVENT FORECASTS**

G. R. HECKMAN. In Jet Propulsion Lab., California Inst. of Tech., Interplanetary Particle Environment. Proceedings of a Conference p 91-100. 15 Apr. 1988.

Avail: NTIS HC A08/MF A01 CSCL 03/2

The United States operates a space weather service to provide information on space hazards including solar proton events to Federal government agencies and other users who operate systems that are affected by disturbances in the upper atmosphere and interplanetary environment. The observation and prediction of solar proton events has been continuous through solar cycle 21 (1976 to 1986), establishing a base of experience that can be used in providing similar support to space operations in the 1990's. The observations, indices, alerts, and forecasts used in the service are described. Also provided is a short summary of the experience

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obtained from making proton event predictions in solar cycle 21 including the years 1976 to 1986. Author

**N89-28485\*** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

### HIGH-ENERGY PARTICLES VERY NEAR THE SUN Abstract Only

B. E. GOLDSTEIN In: *Interplanetary Particle Environment. Proceedings of a Conference* p 117 15 Apr. 1988  
Avail: NTIS HC A08/MF A01 CSCL 03/2

NASA's long range plans include a Solar Probe (Star Probe) mission in which a spacecraft is placed in an eccentric orbit with perihelion at four solar radii. As part of the study effort for this mission, a Solar Probe Environment Workshop was sponsored by JPL. The report of this committee was issued in September 1978 as JPL Publication 78-64. A brief abstract of this document is given. There are considerable uncertainties in the models of solar energetic particle release and transport. The committee addressed this problem by using different modeling techniques when possible to provide a cross-check on the estimates. These models were used to extrapolate observation at 1 AU to the vicinity of the Sun. Additionally, the occurrence of a flare of a given magnitude must be estimated on a statistical basis. Therefore, it is possible to state a likelihood that the fluxes and fluences will be less than a certain magnitude, but in the event of an extremely large solar flare (occurrence of perhaps once a decade, e.g., August 4, 1972) it is likely that the hazard would be insurmountable. A brief first look indicates that the near-solar particle environment is not a worse hazard than Jupiter. Author

### N89-28478# Oak Ridge National Lab., TN. Biology Div. RISK ASSESSMENT AND LATE EFFECTS OF RADIATION IN LOW-EARTH ORBITS

R. J. M. FRY 1989 15 p Presented at the Symposium on Radiation Hazards in Space and Biological Consequences, Washington, DC, 11 May 1989 Sponsored in part by Martin Marietta Energy Systems, Inc.  
(Contract DE-AC05-84OR-21400)  
(DE89-013043; CONF-8905157-1) Avail: NTIS HC A03/MF A01

The radiation dose rates in low-earth orbits are dependent on the altitude and orbital inclination. The doses to which the crews of space vehicles are exposed is governed by the duration of the mission and the shielding, and in low-earth orbit missions protons are the dominant particles encountered. The risk of concern with the low dose rates and the relatively low total doses of radiation that will be incurred on the space station is excess cancer. The National Council on Radiation Protection and Measurements has recently recommended career dose-equivalent limits that take into account sex and age. The new recommendations for career limits range from 1.0 Sv to 4 Sv, depending on sex and on the age at the time of their first space mission, compared to a single career limit of 4.0 Sv previously used by NASA. Risk estimates for radiation-induced cancer are evolving and changes in the current guidance may be required in the next few years. DOE

**N89-28533#** Los Alamos National Lab., NM. Chemical and Laser Sciences Div.

### LABORATORY INVESTIGATIONS: LOW EARTH ORBIT ENVIRONMENT CHEMISTRY WITH SPACECRAFT SURFACES

JON B. CROSS 1989 8 p Presented at the Space Operations Automation and Robotics Workshop, Houston, TX, 25-27 Jul. 1989  
(Contract W-7405-ENG-36)  
(DE89-014280; LA-UR-89-2168; CONF-890799-1) Avail: NTIS HC A02/MF A01

Long-term space operations that require exposure of material to the low earth orbit (LEO) environment must take into account the effects of this highly oxidative atmosphere on material properties and the possible contamination of the spacecraft surroundings. Ground-based laboratory experiments at Los Alamos using a newly developed hyperthermal atomic oxygen (AO) source have shown that not only are hydrocarbon based materials affected but that inorganic materials such as MoS<sub>2</sub> are also oxidized and

that thin (750A) protective coatings such as Al<sub>2</sub>O<sub>3</sub> can be breached, producing oxidation of the underlying substrate material. Gas-phase reaction products, such as SO<sub>2</sub> from oxidation of MoS<sub>2</sub> and CO and CO<sub>2</sub> from hydrocarbon materials, have been detected and have consequences in terms of spacecraft contamination. Energy loss through gas-surface collisions causing spacecraft drag has been measured for a few select surfaces and has been found to be highly dependent on the surface reactivity. DOE

**N89-28873#** McDonnell-Douglas Astronautics Co., Huntington Beach, CA.

### ELECTRIC FIELDS IN EARTH ORBITAL SPACE Final Report

K. A. PFITZER May 1989 30 p  
(Contract N00014-80-C-0796)  
(AD-A209542; AD-E900860) Avail: NTIS HC A03/MF A01 CSCL 04/1

During the last few years we have worked on the entry of solar wind into the magnetosphere and on the control the interplanetary magnetic field (IMF) has on the magnetosphere. Correlative data conclusively prove that both the solar wind and the IMF exert considerable influence on magnetospheric processes, and the magnetospheric substorm in particular. Our work on this subject may be roughly divided into two parts, particle entry and representation of the interaction of the IMF with the magnetosphere. We discuss particle entry first. We have quantitatively determined where on the magnetopause that low energy (solar wind) charged particles can gain entry to the magnetosphere. GRA

## 18

## INTERNATIONAL

Includes descriptions, interfaces and requirements of international payload systems, subsystems and modules considered part of the Space Station system and other international Space Station activities such as the Soviet Salyut.

### A89-34644 ON THE ASYMPTOTIC THEORY OF CONTRAST SPACE STRUCTURES

A. B. VASIL'eva and V. F. BUTUZOV (Moskovskii Gosudarstvennyi Universitet, Moscow, USSR) IN: BAIL, V. Proceedings of the Fifth International Conference on Boundary and Interior Layers - Computational and Asymptotic Methods, Shanghai, People's Republic of China, June 20-24, 1988. Dublin, Ireland, Boole Press, Ltd., 1988, p. 363-367.  
Copyright

The present treatment of the singularly-perturbed system of two second-order equations obtains the asymptotic expansion of the solution having an interior spike layer by means of the boundary-layer functions method. The uniform asymptotic validity of the constructed expansion can be fully proved. It is held to be noteworthy that the third of the 'spike point' types obtained here is also found in the widely known 'brusselator' model. O.C.

### A89-34748 THE PROSPECTS FOR EUROPEAN AEROSPACE TRANSPORTERS. III - APPLICATIONS OF AEROSPACE TRANSPORTERS. IV - HISTORICAL AND POLITICAL CONSIDERATIONS

P. Q. COLLINS (Imperial College of Science and Technology, London, England) and D. M. ASHFORD Aeronautical Journal (ISSN 0001-9240), vol. 93, March 1989, p. 77-82. refs  
Copyright

A small, near-term-developed aerospace transporter would be useful for launching small satellites, servicing satellites in orbit, and supplying space stations, as well as furnishing a technology-development base for subsequent, larger vehicles. These larger vehicles have a potential cost/fly that is estimated



to be of the order of 1000 times lower than that of the NASA Space Shuttle, at traffic levels typical of their use in tourism. An additional part of this work notes that the evolution of space transportation to date has been driven by considerations of defense policy and international prestige, with little priority given to the launch cost reductions that would be of paramount importance to passenger-carrying commercial ventures. O.C.

#### ABN-36325

#### TECHNOLOGY FOR EUROPE - EXAMPLES FROM THE SPACE PROGRAM [TECHNOLOGIE FUER EUROPA - BEISPIELE AUS DER WELTRAUMFAHRT]

HEINZ STOEWER. Luft- und Raumfahrt (ISSN 0173-6264), vol. 10, 1st Quarter, 1989, p. 18-20. In German. Copyright.

The scientific, technological, and economic benefits of ESA space programs are surveyed. Topics addressed include economic studies indicating a multiplication effect of space-program expenditures; existing commercial space enterprises such as Eutelsat, Inmarsat, Intelsat, ArianeSpace, and Spottimage; and proposed organizations such as AgriSpace, EcoSpace, SpaceRescue, Detatel, and Enerspace. The unique value of the information provided to science, industry, and agriculture by space remote sensing is discussed, and the future potential of space activities is considered in terms of broader issues such as space colonization and possible interaction with extraterrestrial life. T.K.

#### ABN-36326

#### MORE THAN JUST ONE SCENARIO - THE CONSTRUCTION AND EXPANSION OF AN ORBITAL INFRASTRUCTURE IN CONNECTION WITH THE INTERNATIONAL SPACE STATION [MEHR ALS NUR EIN SZENARIO - AUF- UND AUSBAU EINER ORBITALEN INFRASTRUKTUR IN VERBINDUNG MIT ISS]

MICHAEL FICK. Luft- und Raumfahrt (ISSN 0173-6264), vol. 10, 1st Quarter, 1989, p. 40-44. In German. Copyright.

An overview of plans for the IOC phase of the International Space Station is presented, with an emphasis on the European role. The main ESA contributions (Attached Pressurized Module, Man-Tended Free Flyer, and Polar Platform) and their missions are described; the tasks of the OMV, OTV, Ariane Transfer Vehicle, and Space Shuttle in the initial assembly of the Space Station are outlined; future launch systems such as the second-generation Shuttle, transatmospheric vehicles, and the NASA Advanced Launch Vehicle and Heavy-Lift Launch Vehicle are briefly characterized; the TDRS/RSS communication network is discussed; and the development of a crew evacuation and rescue system is considered. Drawings, diagrams, and photographs from recent Space Shuttle missions are included. T.K.

#### ABN-36541\* Baylor Univ., Waco, TX.

#### TRANSPORT DYNAMICS CALCULATED UNDER THE FULL MIE SCATTERING THEORY FOR MICRON AND SUBMICRON LUNAR EJECTA IN SELENOCENTRIC, CISELUNAR, AND GEOCENTRIC SPACE

T. W. HYDE and W. M. ALEXANDER (Baylor University, Waco, TX). In: Lunar and Planetary Science Conference, 19th, Houston, TX, Mar. 14-18, 1988, Proceedings. Cambridge/Houston, TX, Cambridge University Press/Lunar and Planetary Institute, 1989, p. 807-814. refs. (Contract NAGW-1282) Copyright.

In 1967, Lunar Explorer 35 was launched from the earth and placed into a stable orbit around the moon. The data from the dust particle experiment on this spacecraft were essentially continuous over a 5-yr period from the time of insertion in lunar orbit. Analysis of this data has been interpreted to show that micron-sized lunar ejecta leave the moon and traverse through selenocentric and cislunar space and obtain either interplanetary/heliocentric orbits or intercept the earth's magnetosphere and move into geocentric orbits. Extensive studies of the or-

bitary trajectories of lunar particles in this size range have now been conducted that include a calculation of the solar radiation force using the full Mie scattering theory. A significant flux of particles with radii less than 0.1 micron are found to intercept the earth's magnetopause surface. This flux is shown to be strongly dependent upon both the particle's density and its index of refraction. Author

#### ABN-36554

#### SATELLITE ASTRONOMY: THE PRINCIPLES AND PRACTICE OF ASTRONOMY FROM SPACE

JOHN K. DAVIES (Royal Observatory, Edinburgh, Scotland) Chichester, England/New York, Ellis Horwood, Ltd./Halsted Press, 1988, 209 p. refs. Copyright.

The history, aims and principles, techniques and instrumentation, and major findings of space astronomy are reviewed in an introduction for the general reader. Chapters are devoted to the design, launch, and orbital parameters of satellite observatories; X-ray astronomy satellites; gamma-ray observatories; UV and EUV astronomy; plans for optical astronomy with the Hubble Space Telescope; IR and mm-wave astronomy; space radio astronomy; and plans for observations from the Space Station, satellite clusters, or the moon. Extensive drawings, diagrams, photographs, and tables of numerical data are provided. T.K.

#### ABN-36565#

#### THE DYNAMICS OF SYSTEMS OF DEFORMABLE BODIES

WILHELMUS PETRUS KOPPENS. Eindhoven, Netherlands, Technische Universiteit Eindhoven, 1989, 112 p. refs.

Numerical techniques for analyzing the dynamic behavior of multibody systems with deformable members are developed analytically. Topics addressed include the equations of motion for a deformable body, the generation of base functions, the equations of motion for a system of bodies, and the assessment of descriptions and approximations. Consideration is given to FEM and modal-synthesis approaches, nonlinearities corresponding to deformation-induced displacements, frequency shifting, and the description of rotational motion in terms of Euler parameters. Diagrams and graphs are provided. T.K.

#### ABN-36680

#### ESA MICROGRAVITY PAYLOADS FOR THE 1990S

G. SEIBERT (ESA, Microgravity Office, Paris, France) (COSPAR, ESA, and International Union of Crystallography, Plenary Meeting, 27th, Symposium on Microgravity, 16th, Espoo, Finland, July 18-29, 1988) Advances in Space Research (ISSN 0273-1177), vol. 8, no. 12, 1988, p. 97-109. Copyright.

Flight opportunities for the existing and new microgravity multuser research facilities on Eureka and Spacelab and design studies for new experimental facilities for Columbus are examined. The results of preliminary microgravity studies are summarized with particular reference to crystal growth, metals and composite materials, fluid science, electrophoresis, cell and developmental biology, and human physiology studies. The current status of payload planning for Space Station/Columbia is then briefly reviewed. V.L.

#### ABN-38031

#### INTERNATIONAL SYMPOSIUM ON SPACE TECHNOLOGY AND SCIENCE, 16TH, HOKKAIDO UNIVERSITY, SAPPORO, JAPAN, MAY 22-27, 1988, PROCEEDINGS, VOLUMES 1 & 2

KYOHEI KONDO, ED. (Tokyo, University, Japan) Symposium sponsored by Hokkaido Aerospace Industry Development Council, Ad Melco Co., Ltd., National Space Development Agency of Japan, et al. Tokyo, AGNE Publishing, Inc., 1988, Vol. 1, 1448 p.; Vol. 2, 1310 p. For individual items see ABN-38032 to ABN-38396. Copyright.

Recent advances in space science and technology are discussed in reviews and reports, mainly from Japan. Topics addressed include propulsion, materials and structures, flight dynamics and astrodynamics, fluid dynamics, thermophysics and

thermochemistry, electronic components and devices, computers and data systems, systems engineering, and space transportation systems. Consideration is given to guidance, navigation, and control; spacecraft systems; the International Space Station and manned space technology; balloons; satellite communication and broadcasting; lunar and planetary exploration; terrestrial remote sensing; space medicine; biology and the cosmos; microgravity; space industrialization; and the Japanese national space program.

T.K.

## ABR-38036

## POSITIVE CONTROL OF CURRENT DISTRIBUTION IN A SEGMENTED-ANODE MPD THRUSTER

YOSHIOH ARAKAWA (Tokyo, University, Japan) and ANDERS E. SOLEM. In: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings, Volume 1, Tokyo, AGNE Publishing, Inc., 1988, p. 27-32. refs. Copyright

The effects of discharge-current (Id) distribution on the performance of a 10-kW-class steady-state segmented-anode Ar/Ni magnetoplasmadynamic (MPD) arcjet thruster are investigated experimentally. A thoriated tungsten axisymmetric anode is split into upstream and downstream sections at the 10-mm-long 8-mm-diameter nozzle throat, and the gap is covered with a BN spacer to prevent erosion; tests of one- and two-anode operation are performed in a 2.5-m-long 0.8-m-diameter vacuum tank at pressure 600 micron and Ar flow rate 9 mg/sec. The results are presented in graphs, and it is shown that low mass-flow rate, high magnetic field, and low Id all tend to move the Id distribution downstream, theoretically making control easier. A high-mode discharge at Id = 100 A is found to be particularly promising.

T.K.

## ABR-38071

## FABRICATION AND TESTING OF THE GR/EP SPHERICAL MIRROR WITHOUT GLASS BASE - PROPOSAL FOR POWER AND PROPULSION MISSION OF SFU

HIDEO MORITA, MASAHIRO OGUMA, SHINTARO ENYA, JOJI SHINOHARA (Ishikawajima-Harima Heavy Industries Co., Ltd., Yokohama, Japan), and NOBUHIRO TANATSUGU (Institute of Space and Astronautical Science, Sagami, Japan). In: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings, Volume 1, Tokyo, AGNE Publishing, Inc., 1988, p. 345-350. Copyright

Lightweight and shatterproof mirrors for the Solar Dynamic Power System have been developed. The body of the mirrors is a sandwich structure with graphite/epoxy skin sheets and an aluminum honeycomb core. A surface of the skin sheets is covered with resin base and polished to obtain a mirror surface. Flat mirrors are fabricated as preliminary models to validate the design and the fabrication process.

Author

## ABR-38073

## LONG-TERM RELIABILITY OF NEW THERMAL CONTROL MATERIALS

TOSHIHIRO ICHINO, TOSHIO HORIE, YOSHINORI HASUDA, and SHIGEKUNI SASAKI (Nippon Telegraph and Telephone Public Corp., Applied Electronics Laboratories, Musashino, Japan). In: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings, Volume 1, Tokyo, AGNE Publishing, Inc., 1988, p. 357-362. refs. Copyright

The reliability of new thermal control materials, polyetherimide optical solar reflector (PEI-OSR) and inorganic white paint (IWP), is assessed for long-term missions on geostationary-orbit satellites. Electron, proton and UV irradiation tests, and a thermal cycle test, are conducted, simulating the space environment. Thermal control properties after 15 years for PEI-OSR and after 10 years for IWP are predicted to be 0.31/0.82 and 0.55/0.88, indicating good resistance to space radiation. In addition, no weight loss is observed in PEI-OSR or IWP due to oxygen plasma irradiation equivalent to

9 days in LEO. These results indicate that PEI-OSR and IWP are promising thermal control materials for future large-scale satellites.

Author

## ABR-38074

## ATOMIC OXYGEN FLOW FACILITY USING ARCJET

MASAHIRO ISHII, MASAHIRO ITO (Ishikawajima-Harima Heavy Industries Co., Ltd., Yokohama, Japan), KYOICHIRO TOKI, and KYOICHI KURIKI (Institute of Space and Astronautical Science, Sagami, Japan). In: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings, Volume 1, Tokyo, AGNE Publishing, Inc., 1988, p. 363-368. Copyright

Experimental research has been conducted on an atomic oxygen flow facility which simulates atmospheric interactions in low earth orbit. A dc arcjet was used as atomic oxygen source. The arcjet was operated at low power with helium and argon as carrier gases, to which a small amount of oxygen was added. The arcjet possesses a cathode-protected configuration, and contamination due to electrode erosion was not detected. The molecular oxygen was found to be dissociated into atomic oxygen by measuring the beam spectroscopically. Exposure tests for polyimide films were also made. The surface of an aluminized Kapton became rough, and the mass decreased as reported on Space Shuttle. SiO<sub>2</sub>-sputtered and ITO-sputtered polyimide films were effective for atomic oxygen attack.

Author

## ABR-38076

## A STUDY ON A FUNCTIONALLY GRADIENT MATERIAL DESIGN SYSTEM FOR A THRUST CHAMBER

TOHRU HIRANO, TOMOHIKO YAMADA, JUNICHI TERAKI (Daikin Industries, Ltd., Sakai, Japan), MASAYUKI NINO, and AKINAGA KUMAKAWA (National Aerospace Laboratory, Kakuda, Japan). In: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings, Volume 1, Tokyo, AGNE Publishing, Inc., 1988, p. 375-380. Research supported by the Science and Technology Agency of Japan. refs. Copyright

As one of the advanced materials suitable for the thermal barrier of a space plane, a "functionally gradient material" (FGM) is proposed. The FGM uses different material components, such as ceramics and metals, and has gradually changing mixture ratio of the components. An FGM design system based upon the inverse design concept is proposed for the development of advanced rocket thrust chambers and other structural components which are exposed to temperature differences of more than 1000 K within the thickness. The FGM is quite effective for decreasing the thermal stress induced in the high temperature difference. In order to verify the design procedure, metal/plastic FGMs are fabricated, and the temperature distribution through the thickness is measured and compared with the design value.

Author

## ABR-38081

## DEPLOYABLE TRUSS BEAM (DTB) STRUCTURAL MODELS

YOSHINORI FUJIMORI, SEISHIRO KIBE (National Aerospace Laboratory, Chofu, Japan), TATEO HOSOMURA, YASUO KUMAGIRI (Nissan Motor Co., Ltd., Tokyo, Japan), HIROSHI KOMINE (Mitsubishi Electric Co., Ltd., Amagasaki, Japan) et al. In: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings, Volume 1, Tokyo, AGNE Publishing, Inc., 1988, p. 431-436. Copyright

The Deployable Truss Beam (DTB) has seen some progress in the past two years with fabrication of truss structural models. Two kinds of models, one the all-rigid-member truss, another the tension-strand truss have been provided for technical evaluations. Two truss models were compared in a functional test to measure static deploy/retract force. Also, static rigidity tests in axial, bending, shear and torsion modes as well as dynamic test were carried out to assess the structural integrity.

Author

AB9-38082

**CONCEPT OF A HELICAL LATTICE BEAM AND ITS CHARACTERISTICS**

MICHIHIRO NATORI, KORYO MIURA (Institute of Space and Astronautical Science, Sagami-hara, Japan), and SABURO MATUNAGA. IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 437-445. refs

Copyright

A new structural concept of a helical lattice structure for space applications is proposed. It consists of many continuous structural members, and they are connected at some cross points to give a suitable structural configuration. It aims at easy construction of large space structures in space. Among a wide variety of helical lattice structures a helical lattice beam is the most fundamental element, chiefly focused in this paper. Two basic theorems on the helical lattice beam configuration and their corollary are introduced. The mechanical (both static and dynamic) properties of the configurations are examined by FSM. Author

AB9-38083

**EFFECTS OF RANDOM MEMBER LENGTH ERRORS ON THE ACCURACY OF LATTICE SPACE STRUCTURES**

HIROSHI FURUYA (Nagoya University, Japan). IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 447-452. refs

Copyright

The effects of random member length errors on the accuracy of lattice structures have been formulated analytically. The formulas have been derived for expected value and variances of the rms distortion ratio based on the assumption of zero-mean normally distributed random errors in measured distortions. As numerical examples, statically determinate and indeterminate cantilevered/free-free trusses, and tetrahedral truss antenna reflectors, have been investigated. Author

AB9-38084

**THE REFLECTOR SURFACE ACCURACY AND THE SHAPE ADJUSTMENT ALGORITHM OF THE TENSION TRUSS ANTENNA**

KORYO MIURA, MASAMORI SAKAMAKI, YASUYUKI MIYAZAKI (Institute of Space and Astronautical Science, Sagami-hara, Japan), TETSUO YASAKA, ISAO OHTOMO (Nippon Telegraph and Telephone Public Corp., Communication Satellite Technology Laboratory, Yokosuka, Japan) et al. IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 453-458.

Copyright

This paper deals with the reflector surface sensitivity and the reflector shape control of the Tension Truss Antenna (TTA). TTA is a concept for a mesh-surface deployable antenna, whose reflector surface is composed of a reflective mesh and a cable network, called a tension truss. The tension truss supports, and gives the parabolic shape to, the reflective mesh, and the shape of the tension truss is determined by the cable lengths and their arrangement. The effect of the random-length error of tension truss cables on the surface shape is evaluated by using a Monte Carlo simulation technique. It is clarified that the large cable-length errors result in large surface deformations due to cable slackings. Results show that the surface deformations can be adjusted by changing lengths of cables, and the adjustment can be performed without affecting the other part of the surface. Author

AB9-38085

**A REFLECTOR CONCEPT USING INFLATABLE ELEMENTS**

MICHIHIRO NATORI (Institute of Space and Astronautical Science, Sagami-hara, Japan), HIROSHI FURUYA (Nagoya University, Japan), SUMIO KATO, YASUHIRO TAKESITA, and TOSHINORI SAKAI (Kawasaki Heavy Industries, Ltd., Aircraft Engineering Div., Kakamigahara, Japan). IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988,

Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 459-467. refs

Copyright

A concept of a modularized inflatable space structure for various high precision reflector missions in the relatively near future is proposed to avoid some difficulties of conventional inflatable concept, such as the lack of hard-points, and the requirement for a precisely accurate manufacturing process. Some fundamental characteristics for surface accuracy of inflatable elements are studied, and appropriate reflector systems including these elements and a truss back structure are introduced. Author

AB9-38086

**DEVELOPMENT OF SPIRAL DEPLOYABLE RIB ANTENNA**

HIDEKI NUKADA and YUJI TSUTSUMI (Toshiba Corp., Kawasaki, Japan). IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 469-474.

Copyright

The structural concept of a deployable space antenna is fundamental to space structural engineering. This paper presents a new type of large deployable space antenna. This antenna, with a mesh surface, has several ribs which can be folded spirally around its center axis. When the ribs are folded, the antenna packaging size becomes very small. An experimental model was developed and its deployment function was tested. Author

AB9-38087

**GROUND TESTING METHOD FOR LARGE DEPLOYABLE ANTENNA**

AKIRA MEGURO (Nippon Telegraph and Telephone Public Corp., Communication Satellite Technology Laboratory, Yokosuka, Japan). (Japan Society for Aeronautical and Space Sciences, Journal, vol. 36, no. 414, 1988, p. 326-332) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 475-480. Previously cited in issue 01, p. 17, Accession no. AB9-10541.

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AB9-38088

**CONCEPTUAL MODELS OF THE LARGE ON-BOARD ANTENNA FOR MOBILE COMMUNICATIONS SATELLITE**

YUICHIRO BABA, AKIO ISO, KAZUO YAMAMOTO, and YUJI TSUTSUMI (Space Communications Research Corp., Tokyo, Japan). IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 481-490.

Copyright

This paper describes a preliminary study of a large antenna reflector for mobile communications functioning on a geostationary platform, assuming the use of the 800-900 MHz band and an aperture diameter of about 30 meters. Reflector structures are studied, emphasizing their ability to meet increased requirements for surface accuracy and stiffness. Three truss configurations are selected and their partial and scale models are designed and manufactured to confirm the soundness of their structure concept and to study their structural practicality more concretely. Author

AB9-38089

**STRUCTURAL DESIGN CONSIDERATIONS OF LARGE COMMUNICATION SATELLITE ANTENNAS**

YASUO AYATSUKA, YOSHITSUGI YASUI, KOHEI OHATA, and MASAYOSHI MISAHA (Nippon Telegraph and Telephone Public Corp., Radio Communications Systems Laboratories, Yokosuka, Japan). IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 491-495.

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This paper describes structural design for developing large communication satellite antennas. The structural concept and its characteristics in the antenna are described. Structural design considerations of satellite antenna are presented for finite-element



structural approaches: (1) dynamic load estimation on launch stage, and (2) thermal deformation suppression in geostationary orbit. The method and points of two structural approaches are discussed.

Author

#### 89-38091

**STRUCTURAL ANALYSIS METHODS APPLIED TO ETS-VI**  
HIDEHIKO MITSUMA, AKIO TSUJIHATA, KOJI TERADA (National Space Development Agency of Japan, Tokyo), TATSUO KATO, TAKASHI TSUKASHIMA (Toshiba Corp., Kawasaki, Japan) et al. IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 503-508. Copyright

ETS-VI (Engineering Test Satellite VI) is now in its preliminary design phase under contracts of NASDA and is now scheduled to be launched by an H-II rocket in the summer of 1992. This paper describes such details of the structural analysis methods applied to the satellite as their theoretical backgrounds, their data-generation methods, their coupling and synthesis methods and some of their results.

Author

#### 89-38096

**OPTIMAL SUPPORT DESIGN FOR VIBRATION OF SATELLITE ANTENNA REFLECTORS**  
YOSHIHIRO NARITA (Hokkaido Institute of Technology, Sapporo, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 533-538. Copyright

The optimal design problem is considered for satellite antenna reflectors. An analytical model is established for the reflectors, and the governing equation of motion for the model is solved analytically, yielding a frequency equation in simple form. Then, using the support position as a design variable, the fundamental frequency of the reflector model is maximized. For one design parameter problem, a parameter study is made to determine the optimal support position. For the more complicated case of two design parameters, a gradient method is used for optimization, and the optimal position is obtained by an iterative solution process.

Author

#### 89-38139

**FLIGHT PERFORMANCE OF THE ETS-V THERMAL CONTROL SUBSYSTEM**  
M. KITADA, H. MASUMOTO, Y. SAKURAI (Mitsubishi Electric Corp., Kamakura, Japan), Y. KANAMORI, and T. KATAGI (National Space Development Agency of Japan, Tokyo) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 845-855. refs

The Engineering Test Satellite-V (ETS-V), a Japanese geostationary satellite, has been launched by H-II Rocket. The main features of the thermal design of the ETS-V are thermal control using solar absorbers in transfer orbit, apogee boost motor plume protections and monitoring, and heat pipe radiator system using fixed conductance heat pipes and variable conductance heat pipes for high heat dissipating components. This paper describes the outline of this thermal design of the ETS-V and the evaluation of that on the basis of flight data.

Author

#### 89-38149

**NONINTRUSIVE MEASUREMENT OF SURFACE TEMPERATURE DISTRIBUTIONS**  
NORIO ARAI (Tokyo University of Agriculture and Technology, Koganei, Japan) and KIYOSHI SATO (Institute of Space and Astronautical Science, Tokyo, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 929-934. Copyright

An IR camera is used to nonintrusively measure the surface

temperature distributions for 12.45/7 deg bent-nose bionics at Mach 7. It is found that the surface temperature pattern of the bent bionic is influenced by the separation and reattachment of flow. Consideration is given to the importance of vortex-induced heating in designing vehicles such as the bionic Aerostated Orbital Transfer Vehicle.

R.B.

#### 89-38166

**DEVELOPMENT OF A PIEZO LINEAR ACTUATOR FOR AN ADAPTIVE PLANAR TRUSS STRUCTURE**  
KENICHI TAKAHARA, HIROSHI TAKAHASHI, SHITTA SHINGU (Toshiba Corp., Research and Development Center, Kawasaki, Japan), SHOICHI MOTOHASHI, FUMIHIRO KUWAO (Toshiba Corp., Komukai Works, Kawasaki, Japan) et al. IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1053-1057. refs

A piezo linear actuator (PLA), which is driven by using piezoelectric devices, is proposed, and its basic characteristic test results are reported. This PLA will be used in an adaptive planar truss structure, which can purposefully change its geometrical configuration and mechanical characteristics in orbit. According to the test results, the basic performance of the PLA as a linear actuator for use in space has been confirmed in the laboratory.

Author

#### 89-38175

**SPACE STATION JAPANESE EXPERIMENT MODULE COMMUNICATION AND CONTROL SYSTEM**  
T. YOKOYAMA (National Space Development Agency of Japan, Space Station Group, Tokyo), I. EGUCHI, Y. IKI, H. KATO, N. OHGI (NEC Corp., Space Station Systems Div., Yokohama, Japan) et al. IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1117-1122. Copyright

The requirements of the communication and control system for the JEM for the Space Station are discussed. The various components of the system are described, including the network, computer, high-rate data, video, audio, and caution and warning systems. The proposed design of the communication and control system is presented. In addition, plans for using the system for the communication, storage, and transfer of data are examined.

R.B.

#### 89-38176

**SPACE STATION JAPANESE EXPERIMENT MODULE INFORMATION SYSTEM CONCEPT STUDY**  
ISAO IIZUKA, YASUHIKO FUJITA (National Space Development Agency of Japan, Tokyo), KOICHI KISHI, TOMOJI TAKASU, HIRONORI KATO (NEC Corp., Space Station Systems Div., Yokohama, Japan) et al. IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1123-1128. Copyright

Results are presented from a concept study on the information system for the JEM. The information is defined and the system requirements to ensure end-to-end communications are outlined. The services provided by the system are considered, focusing on the transmission of data between space and the ground. The on-orbit and ground elements of the JEM information system, the system interfaces, and the types of data handled by the system are described.

R.B.

#### 89-38177

**SPACE EXPERIMENT SUPPORT SYSTEM**  
KOHTARO MATSUMOTO, MASAO NAKA, HIROMICHI YAMAMOTO, SHOUCHI YOSHIHARA (National Aerospace Laboratory, Chofu, Japan), KIYOSHI TOHDO (Fujitsu FACOM Information Processing Corp., Tokyo, Japan) et al. IN: International Symposium on Space Technology and Science, 16th, Sapporo,

Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1129-1134.

Copyright

The development of an AI-based experiment support system for the JEM is discussed. The feasibility of the concept is examined and results from tests using a system prototype are presented. Consideration is given to the development of two prototype subsystems: an electric manual system to convert the experiment manual into a knowledge base and a mission scheduling system for use in planning experiments. R.B.

#### AB9-38179

##### TOWARDS THE JEM SYSTEM/PAYLOAD OPERATIONS PLANNING EXPERT SYSTEM

TOSHIKO WAKAI and MASANORI HORIO (Fujitsu, Ltd., Space Systems Dept., Tokyo, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1141-1146.

Copyright

The Mission Scheduling Expert Systems, Mises/Mises II, for the JEM is examined. An overview of the design and operation of Mises is given. The algorithms used in determining and evaluating a schedule time are discussed. Results are presented from tests using the system to generate daily schedules. Also, consideration is given to the development of changes to improve the system. R.B.

#### AB9-38192

##### THE GROUND TEST FACILITIES OF SPACE ROBOTICS TECHNOLOGY

YASUO SHINOMIYA, SHIN-ICHIROU NISHIDA, HIROMICHI KAWAUCHI, MASAKI TANAKA, TSUYOSHI KOSUGI (Toshiba Corp., Komukai Works, Kawasaki, Japan) et al. IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1231-1236.

Copyright

The development of Japanese ground test facilities for a system of teleoperation/telepresence control is discussed. The current state of teleoperation/telepresence technology is assessed. A hybrid position/force control system is proposed to reduce the effect of time delay in manipulator operation. Preliminary results are presented from tests using the facilities. R.B.

#### AB9-38194

##### A STUDY OF CMG SYSTEMS - FOR SELECTION AND EVALUATION

HARUHISA KUROKAWA (Mechanical Engineering Laboratory, Tsukuba, Japan) and NOBUYUKI YAJIMA (Institute of Space and Astronautical Science, Sagami, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1243-1249. refs

Copyright

A discriminating method of definite (impassable) singularity of a general SG-CMG system is introduced theoretically. It is shown that a multiparameter configuration has only indefinite (passable) singularity inside its envelope. Several CMG systems are compared by the size of working range and the result shows that more than 8 units are required for keeping efficiency under some units' fault. Author

#### AB9-38200

##### MODEL REFERENCE ADAPTIVE CONTROL OF AUTOMATIC DOCKING SYSTEMS IN SPACE

YAOHUA WU, DI YANG, CHENGYUAN ZHU, SHEJIE XU, and XIAOHAO XU (Harbin Institute of Technology, People's Republic of China) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1281-1286.

Copyright

Problems associated with automatic docking control for two

vehicles in space are examined, using the model reference adaptive control (MRAC) approach. The time-varying command generator tracker concept (Abida and Kaufman, 1982) and the Lyapunov approach are used to design a MRAC algorithm for automatic docking control. Simulations show that the algorithm effectively controls the chaser to realize nonimpact docking. R.B.

#### AB9-38201

##### SYSTEM STUDY OF RENDEZVOUS AND DOCKING

YASUFUMI WAKABAYASHI, HIROYUKI NAKAMURA, YUKIKO YOSHIMOTO (National Space Development Agency of Japan, Guidance and Control Laboratory, Tsukuba), and NORIMASA YOSHIDA (Mitsubishi Electric Corp., Space Systems Dept., Kamakura, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1287-1292.

Copyright

The development of a system for LEO rendezvous and docking missions is discussed. Rendezvous and docking concepts are reviewed and system tradeoffs are listed. The system hardware and software requirements are outlined. The proposed uses of the system include the H-II Orbiting Plane, Hope, going to the JEM, Hope going to the Space Station Advanced Technology Platform (ATP), and the ATP going to Hope. Consideration is given to the key technologies needed to develop the system, the typical mission profile, the present development status of the system, and plans for system verification. R.B.

#### AB9-38203

##### NAVIGATION, GUIDANCE AND CONTROL SUBSYSTEM OF SPACE FLYER UNIT

TOSHIMITSU NISHIMURA (Institute of Space and Astronautical Science, Sagami, Japan), YOSHIOKI KUBO, and TETSUO YAMAGUCHI (Mitsubishi Electric Corp., Kamakura, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1299-1304.

Copyright

The Space Flyer Unit (SFU), a small retrievable, reusable space platform, is reviewed, focusing on the development of the SFU navigation, guidance and control subsystem. The SFU configuration and operational sequence are described, and the requirements of the navigation, guidance, and control subsystem are listed. The subsystem components are discussed, including the Inertial Measurement Unit, the acquisition sun sensor, the pointing sun sensor, the GPS receiver, the reaction wheel and wheel drive, and the magnetic torquer. The operation of SFU in earth-pointing, sun-pointing, and orbit control modes is examined. Also, consideration is given to the control modes, disturbance torques, stabilization of flexible solar arrays, and rendezvous strategy. R.B.

#### AB9-38205

##### STABILITY ROBUSTNESS IN TIME DOMAIN OF ADAPTIVE CONTROL

SHIJIE XU, YAOHUA WU (Harbin Institute of Technology, People's Republic of China), and CHENGYUAN ZHU IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 1. Tokyo, AGNE Publishing, Inc., 1988, p. 1313-1318. refs

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Stability robustness conditions in the time domain of a model reference adaptive control (MRAC) algorithm applied to an automatic docking system are presented. Using the MRAC algorithm, a constant output matrix is obtained, which stabilizes the adaptive control system in the whole range of time-varying parameter perturbations during the final docking approach. It is shown that a diagonal transformation matrix may be used to reduce the perturbation bound. R.B.

A89-38220

**SPACE FLYER UNIT (SFU) - SMALL FREE FLYING PLATFORM**

KYOICHI KURIKI (Institute of Space and Astronautical Science, Sagami-hara, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1411-1416.

Copyright

The objectives and configuration of the Space Flyer Unit (SFU), a reusable free-flying platform, are presented. The thermal control system, electrical power system, navigation, guidance and control system, and reaction control system are described in detail. Experiments to be performed aboard the SFU include an electron propulsion experiment, a space plasma diagnostic experiment, and a microgravity materials experiment. Verification flight test objectives involve the extension and retraction of the flexible solar array, rendezvous with the Orbiter, and thermal control of the payload unit box for the experiments. R.R.

A89-38221

**DESIGN OF POWER SUBSYSTEM FOR FREE FLYER APPLICATIONS**

AKIO USHIKAWA, KEIJI TAKAHASHI (Institute of Space and Astronautical Science, Sagami-hara, Japan), NOBORU WAKASUGI, TERUO SUZUKI (Institute for Unmanned Space Experiment Free Flyer, Tokyo, Japan), TAKEO KATSUKI (Toshiba Corp., Kawasaki, Japan) et al. IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1417-1422.

refs

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The design, safety considerations, and development schedule for the electric power subsystem (EPS) of the Space Free Flyer, to be launched in the early 1990s, are discussed. The EPS consists of two sets of systems, one on each of the two solar array paddles (SAPs), and is capable of supplying 700-800 W of power if one of the SAPs ceases to generate power and the other is maintained in the normal sun-oriented mode. The power supply characteristics of various battery configurations are considered. R.R.

A89-38223

**CONCEPTUAL DESIGN AND RECENT TEST RESULTS OF SOLAR DYNAMIC POWER GENERATING SYSTEM FOR SPACE EXPERIMENTS**

MASAFUMI NOGAWA, TAKANORI HAMAJIMA, HIROKI ISHIKAWA, YUTAKA MOMOSE (Aisin Seiki Co., Ltd., Second Research and Development Center, Nishio, Japan), and NOBUHIRO TANATSUGU (Institute of Space and Astronautical Science, Sagami-hara, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1437-1442.

Copyright

This paper deals with the preliminary conceptual design of a 3 kW class solar dynamic power generating system for flight demonstration experiments. The system consists of a cavity receiver including thermal heat storage, a free-piston Stirling engine as energy conversion system, and a linear alternator. The free-piston Stirling engine has a displacer piston and two power pistons. In order to decrease vibration, the two power pistons are arranged in opposing configuration. The power pistons, coupled to permanent magnets, directly drive linear alternators which produce ac power. Preliminary test results are presented. Author

A89-38224

**ELECTRICAL POWER SYSTEM OF JAPAN EXPERIMENT MODULE**

YASUAKI KAWAMURA (National Space Development Agency of Japan, Tokyo), MOTOHIRO KOBAYASHI, TOSHIO GOHNAI, and TOSHIO OKAMURA (Mitsubishi Electric Corp., Kamakura, Japan) IN: International Symposium on Space Technology and Science,

16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1443-1450. refs

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This paper summarizes studies conducted in preparation for basic design of JEM electrical power subsystem based on both the present Space Station electrical power subsystem design status and development philosophy of JEM electrical power subsystem. This includes: (1) trade-off study of JEM electrical power subsystem configuration to achieve high efficiency and light weight electrical power subsystem; (2) trade-off study of bus line voltage to achieve high efficiency and light weight subsystem; and (3) design of JEM electrical power subsystem architecture and components. Author

A89-38225

**COMMONALITY ASPECTS AND DESIGN STANDARDIZATION FOR INTERNATIONAL SPACE PROGRAMS**

MANFRED SCHULZE (MBB/ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1451-1456.

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The increasing financial effort for actual or future complex space programs becomes nearly prohibitive for a single nation. By an internationally agreed commonality policy significant program cost savings can be achieved. The report identifies and discusses spacecraft/space station elements which can be candidates for a common development and manufacturing on an international level. A realization requires a careful preparation concerning the program schedule and the technical and organizational constraints. Author

A89-38244

**SYSTEM DESIGN OF THE APPLICATION TECHNOLOGY PLATFORM**

MASAMI IKEUCHI, RYOICHI IMAI (National Space Development Agency of Japan, Tsukuba), NORIKAZU HARA, and MASANARI HOMMA (National Space Development Agency of Japan, Tokyo) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1597-1602.

Copyright

The system design of the Application Technology Platform (ATP), a Space Station coorbiting platform to be launched in 1995 using the H-II launch vehicle is discussed. The Mission Module, Resource Module, and Propulsion Module of the ATP upper level are described, along with the Orbital Replaceable Unit (of the lower level) which contains the equipment necessary for the in-orbit exchange of materials. The design includes such advanced technologies as an autonomous rendezvous-docking two-phase fluid-loop thermal control system, a retractable solar array, and a fiber optics data bus. R.R.

A89-38256

**A MANNED SPACE PLATFORM WITH ARTIFICIAL GRAVITY GENERATING SYSTEM**

KEIJI NITTA, ATSUSHI NAKAJIMA, KOHTARO MATSUMOTO, and SEISHIRO KIBE (National Aerospace Laboratory, Chofu, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1681-1687. refs

Copyright

As a key element of Japan's infrastructure, a new concept of the manned space platform is proposed in this paper. It consists of an artificial gravity section, a microgravity section, and an easy transit mechanism between them and will realize longer and more comfortable stays in space. Author

A89-38266

**JEM AND ITS INTERNATIONAL ROLE**

Y. MORISHITA, N. SAITO, and M. SAITO (National Space Development Agency of Japan, Tokyo) IN: International Symposium on Space Technology and Science, 16th, Sapporo,



Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1751-1755.  
Copyright

The Japanese Experiment Module (JEM) is Japan's contribution to the international Space Station. Through studies and international coordination between 1985 and 1987, the system requirements and role of JEM have been defined. The JEM system requirements and development plans are going to be updated according to a program requirements update in the Program Requirement Review (PRR). PRR is the process used to update and baseline all SS program requirements and plans by integrating NASA's selected contractors' and international partners' concepts and requirements, and technical coordination with NASA. This paper summarizes the activities in 1987 and 1988, and gives an update of JEM system requirements and development plan, as well as the status of technical coordination issues. Author

#### AB9-38267

##### JEM SYSTEM DESIGN STATUS

KUNIAKI SHIRAKI, ISAO IZUKA, and KATSUYOSHI ARAI (National Space Development Agency of Japan, Tokyo) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1771-1776.  
Copyright

The Japanese Experiment Module (JEM) is a multipurpose laboratory to be attached to the Space Station core, and utilized for the material processing, life science, earth observation, science observation, and technology development experiments. NASDA conducted a preliminary study and international coordination on the JEM for 2 years. This paper summarizes the current JEM system design and international technical issues. Author

#### AB9-38268

##### JEM PAYLOAD ACCOMMODATION

KIYOSHI HIGUCHI, KIWAU SHIBUKAWA, YASUO FUJIWARA, and NAOMICHI TAKEDA (National Space Development Agency of Japan, Tokyo) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1777-1782.  
Copyright

The user requirements of the Japanese Experiment Module (JEM), to be flown as part of the Space Station program, are discussed, along with the payload accommodation for the module. Material processing and life science experiments will be carried out primarily in the pressurized module, while the earth observation, communications, and technology development experiments will be conducted in an exposed facility. The resource, operational, and hardware development interfaces between the experiment systems and the JEM system are reviewed. R.R.

#### AB9-38269

##### JEM OPERATIONS CONCEPT

YASUSHI HORIKAWA and AKIRA TANAKA (National Space Development Agency of Japan, Tokyo) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1783-1787.  
Copyright

JEM is scheduled to be launched and attached to the U.S. Space Station core in 1996. The operations of JEM will start with the launch site processing of the JEM system. JEM will then be launched, assembled and verified on orbit. These activities will be followed by initial and mature phase operations which include operations planning, flight control, logistics support, operations analysis, and crew training. Facilities and equipment for these operations are to be prepared at appropriate operation centers in Japan and the U.S. Author

#### AB9-38274

##### DEMONSTRATION OF PERFORMANCE OF JEM EXPOSED FACILITY USING A FREE FLYER (SFU)

NORIO SAITO, MASAO HATADA, KATSUYOSHI ARAI (National

Space Development Agency of Japan, Tokyo), TOSHIO KATOH, and MIKIO MORIOKA (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1813-1817.  
Copyright

EFFU (Exposed Facility Flyer Unit) which is mounted on "SFU" (Space Flyer Unit) will be launched in early 1993 by the H-II launch vehicle and retrieved in June, 1993 by the Space Shuttle. The EFFU main purposes are to demonstrate the design capabilities of the Exposed Facility, attaching the Japanese Experiment Module (JEM) to the Space Station, and the development technologies for the common experiment equipments in space, e.g., the vapor crystal growth apparatus. The EFFU is composed of the Exposed Facility Section (EFS) and experiment equipment. The EFS is equipped with EEU (Equipment Exchange Unit) and an active thermal loop for the thermal control system. Author

#### AB9-38376

##### INTOSPACE'S TASKS AND ROLE IN EUROPEAN INDUSTRIAL RESEARCH UNDER MICROGRAVITY

RAINER M. A. FELLNER (Intospace GmbH, Hanover, Federal Republic of Germany) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 2527-2531.  
Copyright

Technological and economic aspects of space industrialization are discussed from a European commercial perspective. Topics addressed include the organization of an FRG corporation to facilitate commercial space projects on a European scale; promotional, research, and coordinating activities; the severe time limitations imposed on microgravity experiments or manufacturing processes by ground, aircraft, and sounding-rocket techniques; and the much longer experiment durations possible on Spacelab (7-9 d), Eureca (6 months), and Columbus (as required). Also considered are the current learning-phase status of space industrialization and the risks and opportunities of space investment. T.K.

AB9-38795\* Max-Planck-Inst. fuer Extraterrestrische Physik, Garching (Germany, F.R.).

##### MAN-MADE TRANSIENTS OBSERVED BY THE GAMMA-RAY SPECTROMETER ON THE SOLAR MAXIMUM MISSION SATELLITE

ERICH RIEGER, GOTTFRIED KANBACH, CLAUD REPPIN (Max-Planck-Institut fuer extraterrestrische Physik, Garching, Federal Republic of Germany), W. THOMAS VESTRAND, DAVID J. FORREST (New Hampshire University, Durham) et al. Science (ISSN 0036-8075), vol. 244, April 28, 1989, p. 441-444, refs (Contract BMFT-010K-017-ZA/WS/WRK-02754; NAG5-720)  
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Since launch in early 1980 the gamma-ray spectrometer (GRS) on SMM has monitored the sun at gamma-ray energies. In addition to observations of solar flares, cosmic gamma-ray bursts, and precipitating radiation-belt electrons, the instrument has detected a new class of high-energy transient events that cannot be attributed to any of these phenomena. The duration of these transients can range from 1 sec to more than 10 min. The average event rate between 1980 and 1986 was about five per month. However, in February 1987 this rate increased by more than a factor of 25 and continued at this high level until June 1988. These transients can be subdivided into three classes: 511-keV annihilation-line events, particle events, and broad-band photon continuumlike events. It is found that the most likely sources of these events are reactors in earth-orbiting satellites. Author

#### AB9-39002

##### WHAT ROLES FOR ENERGIA AND BURAN?

PHILLIP S. CLARK (Commercial Space Technologies, Ltd., London, England) Interavia Space Markets (ISSN 0256-4212), Mar.-Apr. 1989, p. 12-17.  
Copyright

The applications to which the Soviet Energia heavy payload launch vehicle and Buran manned reusable 'space shuttle' may be put are discussed. The Soviet have issued conflicting statements on the number of Buran orbiters to be built and their planned annual flight rate; they may total between three and five, with 2-4 flights/year. The main use of Buran will be to ferry crews to and from a space station, as well as the delivery and recovery of space station modules. Maximum payload capability of Buran is 30 tons to orbit, and 20 tons for reentry. Energia may be used for Soviet space station assembly, lunar and Mars missions, GEO satellite-launch missions, and numerous 'space industrialization' missions. O.C.

#### ABR-39089

##### MIR COMES DOWN TO EARTH

TIM FURNESS *Flight International* (ISSN 0015-3710), vol. 135, April 15, 1989, p. 46-48.

Copyright

When launched in 1986, the USSR's Mir space station was considered a turning-point from experimental to large-scale activities in space; all its modules were to have been in place by 1990, bringing its weight to 135 tonnes. After a few months of operation, however, it emerged that Mir's operating costs were greater than initially conceived. It is now anticipated that, as new modules are docked to Mir, the space station's orbital decay rate will increase. The next module scheduled for joining with Mir is a 20.6 tonne life support system/EVA work station, and will be followed by another 20-tonne 'technology' module for crystal growth experiments. O.C.

#### ABR-40825

##### COMPARATIVE STUDY OF ASTRONAUT MOTOR BEHAVIOR DURING GROUND TRAINING ( $G = 1$ ) AND DURING ORBITAL FLIGHT ( $G = 0$ ) (ETUDE COMPARATIVE DU COMPORTEMENT MOTEUR DE L'ASTRONAUTE AU COURS DE L'ENTRAÎNEMENT AU SOL / $G = 1$ ET PENDANT LE VOL ORBITAL / $G = 0$ )

CAROLE TAFFORIN (Toulouse III, Université, France) *L'Aéronautique et l'Astronautique* (ISSN 0001-9275), no. 135, 1989, p. 87-96. In French. refs

Copyright

The method of Tafforin et al. (1987) is used to analyze video recordings of the motor behavior of astronauts both during ground training and in orbital flight. Larger variations in orientation (with respect to the longitudinal axis) are noted under microgravity conditions, resulting in a larger repertoire of motor and postural activities. The usual vertical posture with limbs extended noted in gravity is replaced in zero gravity by a diversity of postures in which the limbs are predominantly bent. R.R.

#### ABR-41037#

##### OVERVIEW OF THE ITALIAN SPACE AGENCY TETHER ACTIVITIES

GIANFRANCO MANARINI and ALBERTO LORIA (Agenzia Spaziale Italiana, Rome, Italy) *AIAA, NASA, Agenzia Spaziale Italiana, and ESA, International Conference on Tethers in Space - Toward Flight*, 3rd, San Francisco, CA, May 17-19, 1989, 17 p. (AIAA PAPER 89-1800)

The Tethered Satellite System (TSS) Program, which involves a reusable tether deployer/retriever system being developed jointly by NASA and the Italian Space Agency ASI is discussed. The objectives of the program and the activities of the various teams involved are summarized. Brief descriptions are given of the various projects, including the Science and Application Tethered Platform, small tethered pointing platforms, Tethered Space Elevator, complex tether technology, payload orbital transfer and reentry, Rendezvous and Docking Facility, Space Station gravity gradient stabilization by tethers, Tether-Initiated Space Recovery System, Tether Inspection and Repair Experiment, and Astrophysical Sciences Tethered Retrievable Observatory. C.D.

#### ABR-41451

##### SPACE AND COMMUNICATIONS - A MARRIAGE MADE IN THE HEAVENS?

CHRIS HAYWARD and SIMON MARA (Marconi Computer Systems, Ltd., Bristol, England) *British Interplanetary Society, Journal* (ISSN 0007-084X), vol. 42, May 1989, p. 187-194. refs

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The history of the development of communications satellites is examined, focusing on the role of satellites in modern communications systems. Consideration is given to the development of automatic repeat request systems, forward error correction techniques, and worldwide tracking, telemetry, and control networks. Emphasis is placed on the relationship between communications systems and satellite technology in Europe. The present status of the satellite communications industry is evaluated and possible future developments in the industry are noted, including the introduction of the Integrated Services Digital Network and the role of the Space Station in communications. R.B.

#### ABR-41453

##### ERSATZ - A SIMULATION OF THE FIRST EUROPEAN REMOTE SENSING SATELLITE

BEV DAVIES and TIM BAUD (Marconi Computer Systems, Ltd., Aldermaston, England) *British Interplanetary Society, Journal* (ISSN 0007-084X), vol. 42, May 1989, p. 205-212.

Copyright

This paper describes the purposes for which the generic spacecraft simulator is used, the functions it has to perform and the special constraints which force it to work the way it does. It describes the advanced features of the biggest and most complex simulator yet developed at ESOC: ERSATZ, which models ERS-1. The paper concludes with an assessment of the likely impact this project could have on future spacecraft simulations at ESOC, both in terms of design philosophy and implementation approach. Author

#### ABR-41455

##### THE COLUMBUS PROGRAMME - TAKING THE USER INTO THE THIRD MILLENNIUM

H. KELLHER and P. J. BOSTOCK (Marconi Computer Systems, Ltd., Bristol, England) *British Interplanetary Society, Journal* (ISSN 0007-084X), vol. 42, May 1989, p. 221-230. Research supported by ESA, DFVLR, and British National Space Centre.

Copyright

The European Space Agency's Columbus program, incorporating the Polar Platform, Free Flying Laboratory, and Attached Laboratory, will bring radical change in the way that instrument users are involved in mission operations. This paper describes how users are likely to be involved in the program, covering their activities chronologically - starting from the time at which the potential user learns about Columbus through to the completion of the instrument's flight operations. Author

#### ABR-41456

##### THE MANNED SPACE-LABORATORIES CONTROL CENTRE (MSCC)

C. PEAT and W. SALTER (Marconi Computer Systems, Ltd., Bristol, England) *British Interplanetary Society, Journal* (ISSN 0007-084X), vol. 42, May 1989, p. 231-238.

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The MSCC will become one of Europe's main control centers for manned space missions. These missions will include the German Spacelab D-2, payload operations coordination for the Columbus Attached Laboratory and both systems and payload operations for the Free Flying Laboratory Marconi personnel have been extensively involved in the definition of the MSCC which is to be set up at the DLR site in Oberpfaffenhofen, West Germany. These missions, particularly Columbus, will place high performance requirements on the MSCC in terms of data rates, mission planning and reliability. This paper details the MSCC definition and includes descriptions of the new areas of technology being developed such as advanced operator consoles based on powerful workstations

with state-of-the-art man-machine interfaces, and expert systems for performing higher level functions such as fault diagnosis.

Author

#### ABR-41458

##### THE HUMAN COMPUTER INTERFACE

A. E. HEMSLEY-BLAKEY and J. C. LEWIS (Marconi Computer Systems, Ltd., Aldermaston, England) British Interplanetary Society, Journal (ISSN 0007-084X), vol. 42, May 1989, p. 247-254.

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Issues related to the design of a human computer interface are reviewed, emphasizing the development of a user friendly system. Consideration is given to the importance of understanding the user's needs when designing the system's information, presentation, and operation. The ergonomic and hardware issues related to interface development are discussed. Four systems are described as examples of interface development: a PC-based user interface, the German Space Operations Center satellite control system, the ESOC satellite control system, and the computer system for the Columbus program.

R.B.

#### ABR-42467

##### CONDUCTING EXPERIMENTS WITH LARGE SCIENTIFIC INSTRUMENTS ON BOARD A SPACECRAFT (OSOBENNOSTI PROVEDENIA EKSPERIMENTOV S KRUPNOGABARITNYMI NAUCHNYMI PRIBORAMI, USTANOVLennyMI NA KOSMICHESKOM APPARATE)

M. I. BELIAEV, V. N. VORONKOV, V. M. STAZHKOV, and T. N. TIAN. IN: Pioneers of space and the present age. Moscow, Izdatel'stvo Nauka, 1988, p. 38-42. In Russian. refs

Copyright

Characteristic problems associated with the use of large scientific instruments in space are briefly reviewed with particular reference to the operation of the KRT-10 radio telescope with a deployable antenna on board the orbital station Salyut 6. In particular, attention is given to the problem of fuel-efficient spacecraft control during the orientation of the large instrument toward the objects to be observed and compensation for the effect of the lack of structural rigidity in the system spacecraft-instrument on the experimental results. Methods of dealing with these problems are discussed.

V.L.

#### ABR-42468

##### SCIENTIFIC EXPERIMENTS AND STUDIES ON THE MANNED ORBITAL STATION SALYUT 6 (NAUCHNYE EKSPERIMENTY I ISSLEDOVANIYA NA ORBITAL'NOI PILOTIRUEMOI STANTSII 'SALYUT-6')

V. M. BALEBANOV and A. V. ZAKHAROV. IN: Pioneers of space and the present age. Moscow, Izdatel'stvo Nauka, 1988, p. 121-137. In Russian. refs

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The program of scientific experiments conducted on the orbital space station Salyut 6 by several different crews over the 4 years and 11 months of the active operation of the station is reviewed. Particular attention is given to a variety of astrophysical and geophysical observations made with the KRT-10 space radio telescope with a 10-m-diameter deployable antenna. Other studies discussed include experiments with the submillimeter telescope BST-1M, testing of the helium refrigerator used in the active cooling system of the telescope, gamma astronomy experiments using the Elena-F gamma telescope, and cosmic ray experiments.

V.L.

#### ABR-43074P

##### THE HERMES ROBOT ARM (HERMES ROBOT ARM)

D. F. KUIPER (Fokker Space and Systems, Amsterdam, Netherlands) Ruimtevaart, vol. 38, April 1989, p. 20-30. In Dutch.

The design concept, applications, and present status of the Hermes Robot Arm (Hera), a telemanipulator system being developed for use with the ESA space shuttle Hermes, are discussed and illustrated with extensive drawings and diagrams. A general overview of the roles of Hermes and the MTFF in the

International Space Station scenario is given, and the use of Hera to handle orbit-replaceable units, manipulate large structural components, or serve as a mobile platform for astronauts during EVAs is described. Particular attention is given to the functions of Hera during Hermes servicing of the MTFF; the Hera arm structure, end-effector, control system, and simulation and test facilities; and the organization of the Hera R&D program. Specific engineering goals for the immediate future are outlined.

T.K.

#### ABR-43075P

##### THE HERA SIMULATION FACILITIES (DE HERA SIMULATIEFACILITEITEN)

J. J. M. PRINS (Nationaal Lucht- en Ruimtevaartlaboratorium, Noordpost Polder, Netherlands) Ruimtevaart, vol. 38, April 1989, p. 31-36. In Dutch.

The design and operation of the ground simulators for the Hermes Robot Arm (Hera) are described. Hera is a telebotonic manipulator arm to be mounted on the ESA space shuttle Hermes; its primary purpose is the efficient servicing of the Columbus Man-Tended Free Flyer. The Hera simulation facility comprises two versions: (1) a non-real-time reference version for the evaluation of design concepts and system software; and (2) a real-time version for hardware-in-the-loop tests, evaluations of the Hera man-machine interface, and to support the development of a crew training simulator. The individual components of these two versions and the system computer architecture are described in detail and illustrated with diagrams, drawings, and photographs.

T.K.

#### ABR-43635

##### ADVANCED POWER SUPPLY AND DISTRIBUTION SYSTEMS FOR COLUMBUS

GERT EGGERS (AEG AG, Wedel, Federal Republic of Germany) Space Power (ISSN 0951-5089), vol. 7, no. 3-4, 1988, p. 267-292.

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Consideration is given to the power supply and distribution systems which are being developed for the Columbus program to provide between 8 and 30 kW to users in low earth orbits. The electrical power system requirements and the power system configuration are described. The effects of a low earth orbit environment on the electrical power system are examined. The solar array for the system is discussed and illustrated. In addition, the functions of the system are examined, including energy storage and power conditioning, distribution, management, and control.

R.B.

#### ABR-43899

##### MIR MISSION REPORT - COSMONAUTS LEAVE MIR UNMANNED

NEVILLE KIDGER. Spaceflight (ISSN 0038-6340), vol. 31, June 1989, p. 191-194.

Copyright

Activities on the Mir space station between August, 1988 and April, 1989 are reviewed. The docking of unmanned cargo craft to deliver supplies to the station, astronomical and earth observations, biomedical experiments, EVA activities, ground-based tests of the Optizont module for crystal growth, and the process of repairing instruments on the station are examined. In addition, consideration is given to studies of the radiation levels in the station, the return of the Mir crew to earth, and plans for commercializing the Mir station.

R.B.

#### ABR-44278

##### PRESENT STATUS AND FUTURE PLANS OF THE JAPANESE EARTH OBSERVATION SATELLITE PROGRAM

KIYOSHI TSUCHIYA (Chiba University, Japan), KOHEI ARAI (National Space Development Agency of Japan, Earth Observation Center, Suitama), and TAMOTSU IGARASHI (National Space Development Agency of Japan, Tsukuba Space Center) (COSPAR, International Union of Geodesy and Geophysics, IAGAP, et al., Flinny Meeting, 27th, Symposium, Topical Meeting, and Workshop on Remote Sensing of the Earth's Surface, Espoo, Finland, July



18-29, 1988) *Advances in Space Research* (ISSN 0273-1177), vol. 9, no. 1, 1989, p. 217-224. refs  
Copyright

Japan's NASDA currently operates three earth-observation satellites: the Marine Observation Satellite, the Experimental Geodetic Satellite, and the Geostationary Meteorological Satellite; these satellites employ multispectral, visible/IR, and microwave radiometers. Future earth observation satellites will include the Earth Resources Satellite-1 and the Advanced Earth Observing Satellite; in addition, an Advanced Microwave Scanning Radiometer and Intermediate Thermal IR Radiometer are under development for eventual deployment aboard NASA's polar-orbiting sensor platform. O.C.

#### **A89-44971 INFRASTRUCTURE FOR SCIENTIFIC UTILIZATION OF COLUMBUS APM AND MTFF**

J. BURFEINDT (Kayser-Threde GmbH, Munich, Federal Republic of Germany) and CH. PUETZ (Applied Microgravity Technology (ISSN 0931-9530), vol. 2, June 1989, p. 110-115. Research supported by BMFT. refs  
Copyright

The use of the Columbus Attached Pressurized Module (APM) and the Man Tended Free Flyer (MTFF) as scientific research facilities is evaluated. The instrumentation planned for metal, crystal, fluid physics, and life sciences laboratories included in the Columbus infrastructure are listed. Experiment and mission scenarios are presented, including estimates of the number and duration of experiments which may be performed in the APM and MTFF laboratories. The role of the User Support and Operation Centers in controlling experiments during a mission is discussed. R.B.

#### **A89-46594 JAPAN IS KNOCKING ON HEAVEN'S DOOR**

WILLIAM TRIPLETT (Air and Space (ISSN 0886-2257), vol. 4, Aug.-Sept. 1989, p. 52-63.  
Copyright

Japanese space policies and near-term Japanese space programs are examined. Plans for the JEM on the Space Station, the H-II commercial launch rocket, the H-II Orbiting Plane (Hope), and the development of liquid air cycle engines for booster rockets are discussed. Consideration is given to the research activities of private Japanese aerospace companies, the relationships between NASDA and other government agencies and private companies, cooperation between NASDA and NASA, and the policy-making process in Japan. R.B.

#### **A89-48703 COLUMBUS IV; PROCEEDINGS OF THE FOURTH COLUMBUS SYMPOSIUM, FRIEDRICHSHAFEN, FEDERAL REPUBLIC OF GERMANY, SEPT. 12-15, 1988**

Symposium organized by ESA, Ministry for Science and Technology of Italy, and BMFT. Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, 212 p. For individual items see A89-48704 to A89-48731.  
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Various papers on the industrial and commercial applications of the Columbus mission are presented. Papers on the uses of Columbus are given, including materials science and fluid science experiments, human physiology research, and earth observation from the polar platform. The scientist/user interface in flight control and the involvement of astronauts in payload design are discussed. Other Columbus-related papers are presented on manned system and support technologies, user documentation, the Columbus data management system, optical diagnostic tools for the fluid science laboratory, the Columbus Pressurized Modules, the characteristic features of microgravity payloads for the man-tended free-flyer, payload operations control with users in remote locations, operational design criteria for a user home base, the APM center as a node of the European ground segment, Columbus utilization cost studies, and the optimization of the composite payload resources. C.D.

#### **A89-48704 ORBITAL OPERATIONS IN PERSPECTIVE**

H. H. KOELLE (Berlin, Technische Universität, Federal Republic of Germany) (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 5-10. refs  
Copyright

Aspects of orbital operations (OOs) are discussed. The reasons for OOs and the activities undertaken in OOs are outlined, and past milestones in OOs are summarized. The contributions that humans can make in OOs are discussed and orbital infrastructures being developed for future OO missions are examined, emphasizing mass flows and costs associated with future GEO stations. Expected future milestones in OOs are listed. C.D.

#### **A89-48705 COLUMBUS - PRESENT STATUS**

F. ENGSTROM and G. ALTMANN (ESA, Space Station and Platforms Directorate, Paris, France) (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 11-19.  
Copyright

The Columbus Program represents Europe's contribution, in cooperation with the U.S.A., Japan and Canada in the International Space Station. The status of the present activities is described in this paper. It includes a brief description of the three hardware elements: Columbus Attached Laboratory, Columbus Free-Flying Laboratory, and Columbus Polar Platform. An overview is given on the origin and evolution of the program, the activities related to its initial operation and utilization preparation and the main programmatic aspects such as overall program schedule and cost. The role of the potential users of Space Station elements is stressed in the paper and plans for ensuring good use of the new capabilities available are presented. Author

#### **A89-48706 SPACE SCIENCE WITH COLUMBUS. III**

H. OLTROF (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 21, 22.  
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The potential utilization of the Columbus Space Station infrastructure for space science experiments is addressed. The opportunities offered by the scientific airlock in the attached pressurized module and by the Space Station structural attachment points are discussed. A short description is given of the payloads attached to the Space Station. C.D.

#### **A89-48708 MATERIALS SCIENCE RESEARCH POTENTIAL IN COLUMBUS**

PAUL CLANCY (ESA, Microgravity Office, Paris, France) (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 29-32.  
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The new frontier for materials science (MS) research which will be opened by Columbus is discussed. Progress expected in the areas of diffusion in melts, room temperature semiconductor nuclear detectors, the growth of III-V compounds and organic nonlinear optics materials, and protein crystallization under microgravity is considered. The planned MS use of the Columbus fluid science laboratory, the containerless processing laboratory, the advanced metallurgy laboratory, the combustion facility, the biotechnology facility, and the MTFF facilities are addressed. C.D.

## AB9-48709

## FLUID SCIENCE EXPERIMENTS AND FACILITIES

R. MONTE (Napoli, Università, Naples, Italy) (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 33-40.

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The fluid science experimentation areas for Columbus are categorized and aspects relevant to deriving guidelines for the design and operation of multiuser facilities are considered. The fluid science experimentation requirements in the Columbus scenario are discussed, emphasizing operational conditions that affect the microgravity experiments. Criteria for the conception of new multiuser facilities are given which can cope with the requirements of the user community and with the constraints of the APM. C.D.

## AB9-48710

## RESEARCH ON BIOLAB, A MULTI-USER FACILITY FOR APM

MARIANNE COGOLI and AUGUSTO COGOLI (Zurich, Eidgenössische Technische Hochschule, Zurich, Switzerland) (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 41-45. refs

(Contract ESA-7695/88/F/FL)

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The results of a study on the design of the Biolab biological laboratory for Columbus APM are discussed. The major scientific and technological objectives of the facility are identified, and the essential equipment to achieve these objectives is described. The accommodation of these instruments within the racks available is addressed, and the crew involvement in Biolab operation is discussed. C.D.

## AB9-48711

## HUMAN PHYSIOLOGY LABORATORY ON COLUMBUS

FLEMMING BONDE-PETERSEN (National Hospital, Copenhagen, Denmark) (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 47-50.

Copyright

The scientific objectives of the human physiology laboratory on Columbus are outlined, and the functional requirements for attaining those objectives are discussed. These include the further development of the Anthracite core elements, service elements, and experiment-specific elements. The topics to be studied in animal physiology are outlined and a large variable centrifuge for this purpose is described. The Columbus Mission Implementation Organization is discussed. C.D.

## AB9-48712

## FLIGHT CONTROL - SCIENTIST/USER INTERFACE

V. HANSEN (Hansen International, Inc., Seabrook, TX) (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 55-57.

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The roles of astronauts and users in the development of the Columbus/Space Station Program are discussed, with emphasis on the interface with flight control. The realization of objectives of users is examined, and anticipated capabilities of the system to meet these objectives, as well as anticipated restrictions, are considered. It is argued that the user community should seek to implement their requirements at this time, when changes to the tentative baseline are at a minimum. The user who knows exactly the operational requirements for his payload will best be served

using the telepresence concept, because the envelope of provided capabilities will be negotiated in advance. C.D.

## AB9-48713

## THE INVOLVEMENT OF ASTRONAUTS IN PAYLOAD DESIGN

D. E. MULLINGER (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 59, 60.

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Potential contributions which astronauts can make to the design of original payloads are pointed out. A method for astronaut involvement in this process is outlined. Such a process would involve discussions with experimenters and facility developers, design review with the developer, review of major program milestones with the appropriate payloads group, participation in safety reviews, and postoperations debriefing. The benefits that astronauts can provide by contributing to each of these points are mentioned. C.D.

## AB9-48714

## THE CONCEPT OF MISSION IMPLEMENTATION

## ORGANIZATION OF COLUMBUS UTILIZATION

R. JONSSON (ESA, Space Station and Platforms Directorate, Paris, France) (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 65, 66.

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In order to encourage users from different disciplines to use Columbus as their laboratory, an attractive utilization concept must be established. Key issues for user operations are identified, and the compatibility of the utilization concept with the Space Station MOU and with the concept finalized by the Central Design Authority is addressed. The mission implementation organization (MIO) concept for utilization is reviewed, and the MIO schedule is described. C.D.

## AB9-48715

## GERMAN APPROACH TO USE COLUMBUS

GOTTFRIED GREGER (BMFT, Bonn, Federal Republic of Germany) (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 69-81.

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The scientific and flight programs involved in the German approach to using Columbus are outlined in detail. The tasks of the scientific centers involved in this utilization and their integration are addressed. Examples of collaborative research projects in the German approach to Columbus use are given, and Spacelab mission planning for Columbus preparation is discussed. C.D.

## AB9-48717

## USER DOCUMENTATION EVOLUTION, PLANNING AND IMPLEMENTATION FOR COLUMBUS MISSIONS

R. A. HENDERSON (RSI, Darmstadt, Federal Republic of Germany) and S. PRESS (DLR, Cologne, Federal Republic of Germany) (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 97-104. refs

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The status, evolution potential, rationale for content, and role of the Columbus payload data base (CPDB) within the short-term and longer-term mission implementation organization for Columbus and the Space Station in Europe are developed. Proposals for activities to implement these concepts to the benefit of both the

European user, the utilization organization, and the interface with the proposed NASA integration scenario are developed within the context of user documentation and the CPDS. C.D.

#### ABN-48718

##### COLUMBUS DATA MANAGEMENT SYSTEM

PH. DELBEY, PH. PITARD, and X. LABORDE (Matra, S.A., Toulouse, France) (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 105-107.

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The data management system (DMS) for Columbus users is discussed with regard to user support requirements. Operational and utilization concepts of autonomy and automation, crew operation support, maintenance and servicing, and remote payload operation for telepresence are considered. The DMS functional and hardware architecture are examined along with fault tolerance and safety. The impact of commonality with international partners is briefly addressed. C.D.

#### ABN-48719

##### OPTICAL DIAGNOSTIC TOOLS FOR A MICROGRAVITY FLUID SCIENCE LABORATORY

A. BASSINI, S. MUSAZZI, U. PERINI (CISE S.p.A., Milan, Italy), and M. GIGLIO (Milano, Università, Milan, Italy) (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 109-113.

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Because of their non-invasiveness, optical techniques appear to be the best candidate for the analysis of fluids as evidenced by the large number of ground-based experiments where experimental setups of this type have been used. For this reason, these techniques have been examined and their applicability to the study of physical quantities in fluid physics experiments to be conducted in a fluid science laboratory operating in the context of a Space Station has been evaluated. Optical methods which allow determination of temperature, density and concentration fields via measurements of the index of refraction will be considered, as well as diffraction-based techniques for the determination of particle (or bubble or droplet) size distribution. Also, techniques for the determination of velocity fields will be examined. Author

#### ABN-48720

##### COLUMBUS PRESSURIZED MODULES TOWARD EUROPEAN MANNED SPACE INFRASTRUCTURE

ERNESTO VALLERANI, LUIGI D'EMILIANO, LUCIANO BASILE, and GUALTIERO BRAMBATI (Aeritalia S.p.A., Turin, Italy) (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 115-130.

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The latest status of the Columbus pressurized module (PM) design is discussed. The PM architecture is reviewed, the main PM characteristics are shown in a table, and the growth capability of the various PM subsystems is addressed. The European manned space infrastructure is examined in detail, including the habitation module and the pressurized logistics module. C.D.

#### ABN-48721

##### CHARACTERISTIC FEATURES OF MICROGRAVITY PAYLOADS FOR THE MAN-TENDED FREE-FLYER

WOLFRAM LORK (Dornier GmbH, Friedrichshafen, Federal Republic of Germany), PAUL CLANCY, and ISABELLE DUVAUX-BECHON (ESA, Microgravity Office, Paris, France) (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany,

Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 131-138.

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The man-tended free-flyer (MTFF) can potentially provide excellent undisturbed conditions of microgravity, up to several months, for experiments in the area of materials and life sciences. But due to the absence of men during the experimental cycles, the facilities will differ from those designed for a permanently manned environment both from the scientific sub-disciplines covered and from the hardware implementation. As far as the sub-disciplines covered are concerned, the MTFF will be more suited to longer duration unattended experiments, such as crystal growth or gravitational biology. As far as the hardware implementation is concerned, emphasis will be more on the machine/facility interfaces to enable automated operation, than on man/facility interfaces known from Spacelab and planned for the attached pressurized module (APM). It will be shown that it is not necessary to design APM-facilities independently from MTFF-facilities, but that it is possible to build them by using common standardized subsystem modules. Payload candidates for the MTFF, outlined in accordance with the new concepts, will be presented as well as the corresponding operational planning. Author

#### ABN-48722

##### PAYLOADS OPERATIONS CONTROL WITH USERS IN REMOTE LOCATIONS - SPACELAB MISSIONS AND BEYOND

K. L. MUELLER and W. WYBORN (DLR, Cologne, Federal Republic of Germany) (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 139-142.

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The Spacelab missions are examined where payload operations control is remote from mission control and user teams are remote from payload operations control. The D1 payload operations and the D2 operational concept are diagrammed and discussed. A possible setup for operations of ESA-payload complement of APM is considered. C.D.

#### ABN-48723

##### OPERATIONAL DESIGN CRITERIA FOR A USER HOME BASE UNDER THE COLUMBUS SCENARIO

K. WEDDE-MUEHLHAUSEN, K. D. SCHMIDT (DLR, Cologne, Federal Republic of Germany), and G. T. BIDDIS (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 143-147.

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A currently fashionable user home base (UHB) concept concerning the Space Station/Columbus mission is for a user to be at his normal place of work where he has all the capabilities necessary for him to support his on-line participation. This paper identifies operational design criteria that will help a potential user to make his own decision as to whether a UHB is feasible for his situation. Previous Spacelab operations scenarios are analyzed in relation to payload operations control center user support, and user room generic interfaces. Experimental/payload operations are analyzed and projected onto a Columbus scenario from which some operational design requirements are derived which would allow a user operations environment to be at least similar to a user room, and possibly more like normal laboratory environments. C.D.

#### ABN-48724

##### OBJECTIVES AND REQUIREMENTS FOR SUPPORTING A COLUMBUS ELEMENT

G. LIPPNER, K. WESSENBERG, and F. URBAN (Dornier GmbH, Friedrichshafen, Federal Republic of Germany) (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany,



Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 149-156.  
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The mission support and the element maintenance and logistics support of the man-landed free flyer (MTFF) of the Columbus mission are discussed. The former includes emergency support, troubleshooting, end-to-end test, and mission preparation support, and the latter includes configuration management. The requirements regarding reference model provision, control architecture, facilities, and operations are described. C.D.

#### AB9-48725

##### COLUMBUS APM CENTER AS A NODE OF THE EUROPEAN GROUND SEGMENT

G. VIRIGLIO, S. LIOY, and L. BATTOCCHIO (Aeritalia S.p.A., Turin, Italy) (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 157-161.  
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A key element of the Columbus attached pressure module (APM) ground infrastructure is the APM center, whose role in the Columbus operations scenario is that of engineering support, payload integration, payload engineering support, logistics, and training. The APM center functions and communications are described in this paper. An architectural concept of the data flow is given. C.D.

#### AB9-48726

##### COLUMBUS UTILIZATION COST STUDIES

G. NAJA (ESA, Space Station and Platforms Directorate, Paris, France) (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 163-165.  
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This paper presents the main results of the utilization cost studies that have been going on in the last year. The aim of these studies is to ensure that economical criteria will be taken into consideration in the technical choices; therefore, the cost studies have been closely linked to the technical studies. Following a global utilization costs estimation, communications, automation, robotics, and mission preparation are analyzed. The results of the corresponding studies are summarized. Author

#### AB9-48727

##### SOME ASPECTS OF LCC REDUCTION FOR IN-ORBIT EXPERIMENTS

K. LOHMANN, S. HOLL (Elektronik System Gesellschaft GmbH, Munich, Federal Republic of Germany), and H. SPRENGER (Intospace GmbH, Hanover, Federal Republic of Germany) (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 167-173.  
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Life Cycle Costs (LCC) related to in-orbit experimentation in the Columbus era will have a strong impact on the affordability of scientific goals obtained from low-g research. As the operating costs tend to get frozen early in the development stage of a project, it is highly desirable to know trends and tendencies of cost driving factors as soon as possible. In this paper the characteristics of selected in-orbit experiments relevant to LCC are described, putting emphasis on the pressurized Columbus elements. State-of-the-art LCC models are introduced and their suitability to represent Columbus-type experiment operations is evaluated. Taking into account costing trends already known, parametric trade-offs based on cost estimating relationships are performed. Following this, possible countermeasures regarding identified cost drivers are taken into consideration. Author

#### AB9-48728

##### DEFINITION OF A SUPPORT ENVIRONMENT FOR DESIGN, DEVELOPMENT AND INTEGRATION FOR PAYLOAD USERS WITHIN THE IOI

A. DEL BUFALO and A. FALCIAI (CISET S.p.A., Rome, Italy) (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 175-179.  
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The role of simulators within the in-orbit infrastructure (IOI) and in support of the user community is discussed. The commonality or reusability of some tools to maximize cost effectiveness is pointed out. The PMS preliminary architecture is described and the PMS functional architecture is depicted and discussed. C.D.

#### AB9-48729

##### OPTIMIZATION OF COLUMBUS COMPOSITE PAYLOAD RESOURCES UTILIZATION BY TRADING ALTERNATIVE REALIZATIONS OF FACILITY FUNCTIONS

G. KAMPFER, O. AFACAN, and W. SCHROEDER (PANARES, Munich, Federal Republic of Germany) (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 181-183. Research supported by DLR.  
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The results of a study of the feasibility of computer-supported optimization of resource utilization of the composite APM and MTFF payload are presented. The optimization allows selection among various options of a particular payload facility configuration which complies best with the overall resource requirements. The individual steps involved in the optimization are outlined, and the individual tasks involved in the optimization are mentioned. The mathematical modeling of the optimization concept is discussed. C.D.

#### AB9-48731

##### HANDLING AND CONTROL OF TRANSATLANTIC DATA TRANSFER DURING PHASE CD

H. ERSFELD (MBB-ERNO, Bremen, Federal Republic of Germany) (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 9, no. 1-2, 1989, p. 189-193.  
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The rules on data and technology transfer during the development and construction phase (C/D) of the Columbus program as outlined in the Intergovernmental Agreement (IGA) and the Memorandum of Understanding (MOU) between NASA and ESA are analyzed from an industry point of view. It is concluded that a complementary agreement between these agencies should be established to facilitate the necessary data transfer in a time- and cost-efficient manner. The reasons for such an additional legal instrument include the complex industrial program structures involved, the time- and cost-saving short links permitted by transatlantic contractor-to-contractor exchanges of data, and the facilitation of expeditious U.S. export control licensing. C.D.

#### AB9-49009

##### GEOLOGY-ORIENTED MODULE FOR ORBITAL SPACE STATION

V. V. EZHKOV (AN SSSR, Soviet Interkosmos, Moscow, USSR), V. V. KOZLOV (Nauchno-Proizvodstvennoe Ob'edinenie Aerogeologia, Moscow, USSR), and N. V. MEZHELOVSKI (Ministerstvo Geologii SSSR, Moscow, USSR) Acta Astronautica (ISSN 0094-6765), vol. 19, May 1989, p. 427-430.  
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Visual observations of geological features on earth were obtained by Salyut-type orbital stations in order to compare the

use of cosmonaut researchers to unmanned satellites for remote sensing from space. The observations have resulted in the detection of several hundred lineaments and ring structures. Associated geological studies have confirmed the geological context of some of these structures, along with their significance as mineral deposits. The space data were used to develop geological maps for planning oil and gas field investigations. The requirements for on-board remote sensing equipment for geological study are briefly discussed. R.R.

#### ABR-48381

##### STRUCTURAL MECHANICS OF SPACECRAFT STRUCTURES [STROITEL'NAIA MEKHANIKA KONSTRUKTSII KOSMICHESKOI TEKHNIKI]

VALERII I. USIUKIN Moscow, Izdatel'stvo Mashinostroenie, 1988, 382 p. In Russian. refs

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The theory and strength analysis of spacecraft, space station, and space-erectable structures are reviewed in a systematic manner with emphasis on computer-based finite element structural analysis methods. The discussion covers the principal equations and variational principles of elastic body mechanics; displacement, force, and mixed finite element methods; finite elements for rod, beam, and plate systems; thin shells; and thermally induced stresses and strains in thin-wall structures. Examples of stability analysis and elements of optimum design are presented. V.L.

#### ABR-48384

##### THERMAL DESIGN PRINCIPLES OF SPACE TRANSPORTATION SYSTEMS [OSNOVYI TEPILOVOGO PROEKTIROVANIYA TRANSPORTNYKH KOSMICHESKIKH SISTEM]

BORIS M. PANKRATOV Moscow, Izdatel'stvo Mashinostroenie, 1988, 304 p. In Russian. refs

Copyright

Thermal design principles are summarized and a complex method for determining the character of space transportation systems with different types of propulsion units is presented. The mechanical and flight characteristics of the system as a whole and of its various components are considered. Methods for determining the basic design parameters are discussed with allowance made for the interaction between the surrounding medium and thermal loading. Particular attention is given to the design of the thermal model and the calculation of the temperature distribution in the spacecraft structure; calculation of heat transfer in vehicle compartments; and the thermal design of descent vehicles. K.K.

#### ABR-50576

##### WALKING IN SPACE - EUROPEAN EVA

DAVID J. BARRON (British Aerospace /Space Systems/, Ltd., Filton, England) Aerospace Dynamics (ISSN 0263-2012), no. 25, 1989, p. 15-21.

Copyright

ESA activities related to the utilization of EVA are discussed. Requirements and factors related to the design of an EVA system are examined. Particular attention is given to the suit associated with the life support system. The tooling and spacecraft-based equipment necessary for interfacing with the suit are considered. I.F.

#### ABR-50685

##### THE SOVIET YEAR IN SPACE 1988

NICHOLAS L. JOHNSON Colorado Springs, CO, Teledyne Brown Engineering, 1989, 187 p. refs

Copyright

Soviet space activities during the year 1988 are characterized on the basis of a review of open-source literature, including Soviet media releases and scientific journals, international technical papers, unclassified satellite-tracking data, and articles in the Western press. Sections are devoted to support systems (launch facilities, launch vehicles, and infrastructure), the major Soviet space programs (photographic-reconnaissance, communication,

navigation, geodesic, meteorological, remote-sensing, scientific, and military satellites; manned missions; and solar-system exploration), the 1988 launches, and the major satellite constellations. Extensive diagrams, drawings, graphs, photographs, and tables of numerical data are provided. T.K.

#### ABR-50686

##### CHANGING TIMES FOR HERMES

Flight International (ISSN 0015-3710), vol. 136, Aug. 5, 1989, p. 26-28.

Copyright

Over the years, the ESA Hermes manned/reusable orbiter has changed from the initially conceived 15-tonne, six-crewmember cargo transporter into a 24-tonne, three-crewmember ferry vehicle designed to dock with a Space Station module. ESA has determined that the Hermes crew requires an escape system to negotiate abortive launches; the weight increase this entails must be compensated for with payload reductions. The primary concern associated with weight increases is not, however, payload limitation so much as the greater thermal stresses borne by a heavier structure upon reentry. The weight increase has further consequences for the Ariane 5 launcher, which must be further optimized for its Hermes mission profile. O.C.

#### ABR-50853

##### APPLICATION OF THE FINITE ELEMENT METHOD TO THE ANALYSIS OF THE NATURAL VIBRATIONS OF SPACECRAFT STRUCTURES [PRIMENENIE METODA KONECHNYKH ELEMENTOV K ISSLEDOVANIYU SOBSTVENNYKH KOLEBANIY KONSTRUKTSII KOSMICHESKIKH APPARATOV]

N. E. NAUMENKO and I. R. KOKZHA Kosmicheskaya Nauka i Tekhnika (ISSN 0321-4508), no. 3, 1988, p. 17-21. In Russian. refs

Copyright

Algorithms for calculating the frequencies and modes of the longitudinal vibrations of inhomogeneous rods are applied to the analysis of the bending vibrations of the rods with allowance for the specific features of the formation of system mass and stiffness matrices. The use of the finite element method for solving problems related to the vibration of spacecraft structures consisting of inhomogeneous rods or systems of rods with concentrated inclusions is discussed. The results are compared with those obtained by other methods. V.L.

#### ABR-51086#

##### THE NEXT GENERATION OF SPACE REMOTE SENSING TECHNOLOGY

MASATOSHI ONO, HIROYUKI FUJISADA, MUNCAZU TACANO, YOSHINOBU SUGIYAMA, MASAKAZU NAKANISHI et al. Electrotechnical Laboratory, Circulars (ISSN 0366-9084), Dec. 1988, p. 1-181. In Japanese, with abstract in English. refs

A survey of the next generation of space remote sensing technology is presented. The achievements of major earth observing satellites are briefly reviewed, and detailed information on various sensors is given. Fundamental sensor calibration principles, innovative solid state devices, radiometer capabilities and limitations, scatterometers, synthetic aperture radars, microwave sensors, laser radars, magnetic sensors, and gravity sensors are examined. An overview of the Space Station is given which includes a polar platform for earth observation. Recent image processing developments pertinent to remote sensing are considered, including both ground and onboard processing approaches. C.D.

#### ABR-51101

##### EUROPEAN SYMPOSIUM ON SPACECRAFT MATERIALS IN SPACE ENVIRONMENT, 4TH, TOULOUSE, FRANCE, SEPT. 6-9, 1988, PROCEEDINGS

Symposium organized by ONERA, CNES, and ESA, Toulouse, France, Cepadues Editions, 1989, 757 p. For individual items see ABR-51102 to ABR-51148.

Copyright

Topics discussed include reentry, long-life missions, in-orbit

testing, and space charging. Consideration is also given to phenomena connected with contamination and impacts, atomic oxygen, and spacecraft glow. Particular papers are presented on high-temperature composite materials for space applications, an approach to the long-term prediction of the effect of atomic oxygen on materials, thermoplastics for space, and the calculation of environmental effects on spacecraft surfaces using Monte Carlo techniques. B.J.

#### AB9-51144

##### CALCULATIONS ON COLLECTED RATIO AND APPARATUS NON-CONCENTRICITY EFFECTS WITH STANDARD ASTM E595-84 TEST METHOD

DA-TONG XUE (Lanzhou Institute of Physics, People's Republic of China) IN: European Symposium on Spacecraft Materials in Space Environment, 4th, Toulouse, France, Sept. 6-8, 1988. Proceedings, Toulouse, France, Cepedues Editions, 1989, p. 647-655. refs

Copyright

A test technique based on the standard ASTM E595-84 method has been used to determine the collected ratio of volatile condensable materials (64.54 percent) and to study the effects of apparatus nonconcentricity on the test results. The difficulty of applying the Monte Carlo method to the present problems is pointed out. The technique involves the usage of Newlyn's diffusion flow calculation method (Essen and Heerens, 1976) and the determination of the geometrical coefficient of an apparatus with nonconcentricity. The results imply that the restriction on nonconcentricity can be extended beyond the 0.1 mm value set by the standard test method. R.R.

#### AB9-51276

##### NATIONAL CONFERENCE ON INDUSTRIAL TRIBOLOGY, TRIVANDRUM, INDIA, JAN. 19, 20, 1989, PROCEEDINGS, VOLUME 1

Conference sponsored by ISRO, Indian Oil Corp., Ltd., Lubrizol India, Ltd., et al. Trivandrum, India, Vikram Sarabhai Space Centre, 1989, 383 p. For individual items see AB9-51277 to AB9-51287.

Topics discussed include friction, wear, and friction drives; lubrication; lubricants; and bearings and rotor dynamics. Attention is also given to IC engines, powerplants, and space tribology, biomedical applications, and the economics and maintenance of tribo systems. C.E.

#### AB9-51507

##### THE ACTION OF SOME FACTORS OF SPACE MEDIUM ON THE ABIOTIC SYNTHESIS OF NUCLEOTIDES

E. A. KUZICHIEVA, N. V. TSUPKINA, and N. G. POTAPOVA (AN SSSR, Institut Tselologii, Leningrad, USSR) (COSPAR, Plenary Meeting, 27th, Topical Meeting and Workshops on the Life Sciences and Space Research XXIII(2): Planetary Biology and Origins of Life, 20th, 21st, and 23rd, Espoo, Finland, July 18-29, 1988) Advances in Space Research (ISSN 0273-1177), vol. 9, no. 6, 1989, p. 53-56. refs

Copyright

Experiments designed to investigate possible states of chemical evolution under conditions of space environment are described. Results from studies aboard Salyut-7 indicate that the synthesis of natural nucleotides can take place abiotically under space conditions and that high temperature (50 C) favors the formation of natural nucleotides. I.S.

#### AB9-51842

##### MAJOR SPACE APPLICATION OF THE 'MIR' SPACE STATION

GEORGI USPENSKI (Glavkosmos SSSR, Moscow, USSR) IN: Space commerce; Proceedings of the Second International Conference and Exhibition on the Commercial and Industrial Uses of Outer Space, Montreux, Switzerland, Feb. 21-25, 1988. New York, Gordon and Breach Science Publishers, 1988, p. 175-180. Copyright

Various applications of the Mir space station are discussed. The configuration parameters of the Mir station are given and the station's facilities are described. The process of using the Mir

station for commercial applications is examined, including the conditions for installing and operating equipment. The equipment and commercial applications available on a commercial basis and the costs of using the station's various facilities are discussed. R.B.

#### AB9-51844

##### EUROPEAN PROGRAMMES IN SPACE-BASED FACILITIES AND TRANSPORTATION

J. COLLET (ESA, Paris, France) IN: Space commerce; Proceedings of the Second International Conference and Exhibition on the Commercial and Industrial Uses of Outer Space, Montreux, Switzerland, Feb. 21-25, 1988. New York, Gordon and Breach Science Publishers, 1988, p. 201-210. Copyright

The components of the European transportation and orbital systems are described. The launching infrastructure is discussed, including the Ariane launchers and the launcher requirements for the 1990s. The orbital infrastructure is examined. The characteristics of Spacelab are outlined and plans for the Columbus/Space Station program are summarized, including the Man-Tended Free Flyer, Hermes, and an unmanned orbital platform. R.B.

#### AB9-51867

##### LOSS OF SPACE VELOCITY

K. GRINGAUZ (AN SSSR, Institut Kosmicheskikh Issledovani, Moscow, USSR) Space Policy (ISSN 0265-9646), vol. 5, Aug. 1989, p. 179-182. Copyright

Problems with the USSR's space budget are discussed. The cost and effectiveness of the space research programs are examined. Resources are allocated for applied research for practical purposes, such as photographing the earth's surface, and for fundamental research related to the study of the outer space proper. Specific examples of Soviet space programs are presented. It is noted that major changes are needed in the plans for developing space vehicles for scientific research, and the control of the space budget by the Soviet Parliament is proposed. I.F.

#### AB9-51889

##### EUROPE'S NEXT MOVE

ROY GIBSON (International Maritime Satellite Organization, London, England) Space Policy (ISSN 0265-9646), vol. 5, Aug. 1989, p. 186, 187. Copyright

Europe's position in the area of space flight is examined. The current status of the Hermes and Columbus programs' development phases is discussed. Reasons for fully financing the programs are presented. I.F.

#### AB9-51891

##### JAPAN'S SPACE POLICY - BACKGROUND AND OUTLOOK

SHIGEBUMI SAITO (Science and Technology Agency, Tokyo, Japan) Space Policy (ISSN 0265-9646), vol. 5, Aug. 1989, p. 193-200. Copyright

This article describes the formation of the Space Activities Commission as the country's primary policy-making body, and of the National Space Development Agency, which oversees the development of space technology. The fundamental guidelines governing space activities are explained, and a detailed breakdown is given of projects agreed to for the coming years. Author



N89-52889

**AN INVESTIGATION OF THE MAXIMUM CAPABILITIES OF INTERORBITAL SPACE TUGS WITH CONTROLLABLE ELECTROCKET ENGINES AND THE CHOICE OF RATIONAL MODES OF THEIR OPERATION IN FLIGHT**  
[ISSLEDOVANIYE PREDEL'NYKH VOZMOZHNOSTEI MEZHORBITAL'NYKH BUKSIROV S REGULIRUEMYMI ELEKTROKETHNYMI DVIGATELIAMI I VYBOR RATSIONAL'NYKH REZHIMOV IKH FUNKTSIONIROVANIYA V POLETE]

G. A. KULAKOV, S. V. PILUTO, and V. F. SAFRANOVICH  
Kosmicheskie Issledovaniya (ISSN 0023-4206), vol. 27, July-Aug. 1989, p. 514-519. In Russian. refs

Copyright

The paper identifies the existence of special (characteristic) points on the family of dependences of the mass of the body pulled by an interorbital tug with electrorocket engines on the initial mass of the tug and the time of electrorocket-engine operation for given values of the propulsion-system power, the separated mass, and the characteristic velocity of the tug. Expressions for the characteristic points are obtained, making it possible to determine lower bounds on the specific impulse of the electrorocket engine.

B.J.

N89-52924

**SPACE MANUFACTURING EQUIPMENT (OBORUDOVANIE KOSMICHESKOGO PROIZVODSTVA)**

IGOR' V. BARMIN, EVGENII I. GORIUNOV, ALEKSANDR V. EGOROV, EDUARD S. IVANCHENKO, ALEKSANDR V. KOTOV et al. Moscow, Izdatel'stvo Mashinostroenie, 1988, 256 p. In Russian. refs

Copyright

This volume examines aspects of the design, adjustment, and operation of equipment for space materials production. Particular attention is given to electrothermal equipment, optical heating equipment, electrophoresis setups, and setups for performing scientific experiments in weightlessness. Attention is given to the design-for-strength of the space manufacturing equipment, its radiation resistance characteristics, design for thermal stability, and the automatic control of the manufacturing equipment.

B.J.

**N89-20157\*** National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.

**CLUSTER: A FLEET OF FOUR SPACECRAFT TO STUDY PLASMA STRUCTURES IN THREE DIMENSIONS**

R. SCHMIDT (European Space Agency, European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) and M. L. GOLDSTEIN. In ESA, The Cluster Mission: Scientific and Technical Aspects of the Instruments p 7-13 Oct. 1988

Avail: NTIS HC A06/MF A01; ESA Publications Div., ESTEC, Noordwijk, Netherlands, \$10 US or 25 Dutch guilders CSCL 22B

The four Cluster spacecraft are spin stabilized spacecraft which are designed and built under stringent requirements as far as electromagnetic cleanliness is concerned. Conductive surfaces and low electromagnetic background noise are mandatory for accurate electric field and cold plasma measurements. The mission is implemented in collaboration between ESA and NASA. A Russian mission will be closely coordinated with Cluster.

ESA

**N89-21946** Centre National d'Etudes Spatiales, Toulouse (France).

**QUALITY, COMPONENTS AND TECHNOLOGICAL ANALYSIS**

Aug. 1988 1246 p. In FRENCH; ENGLISH summary Course held in Toulouse, France, Mar. 1988

(ISBN-2-85-428204-3; ETN-89-93903) Copyright Avail: CEPADUES-Editions, 111 Rue Nicolas-Vauquelin, 31100 Toulouse, France

Product assurance in the space field, system dependability (reliability, availability, safety), quality assurance, software quality assurance, electronic components, VLSI components, microwave and optoelectronic components, and technological analysis were discussed.

ESA

**N89-21947** Centre National d'Etudes Spatiales, Toulouse (France).

**PRODUCT ASSURANCE IN SPACE APPLICATIONS. GENERAL PRESENTATION: PECULIARITY OF SPACE CONTEXT**

GEORGES BERNEDE. In its Quality, Components and Technological Analysis p 29-51 Aug. 1988 In FRENCH; ENGLISH summary

Copyright Avail: CEPADUES-Editions, 111 Rue Nicolas-Vauquelin, 31100 Toulouse, France

Involvement of quality analysis in the different project phases is discussed. The application of the total quality control to space activities and the obstacles found are analyzed. It is shown that economic competition will force the space industry to adopt the total quality concepts.

ESA

**N89-21948** MATRA Espace, Toulouse (France).

**IS THERE MANAGEMENT QUALITY IN LARGE PROJECTS [Y-A-T-IL UNE QUALITE DE MANAGEMENT DE GRANDS PROGRAMMES]**

ALAIN DECACQUERAY. In CNES, Quality, Components and Technological Analysis p 53-72 Aug. 1988 In FRENCH; ENGLISH summary

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Quality rules pertinent to management functions are discussed and related to the necessity of integrating these rules to an overall quality assurance policy. Efficient management rules leading to success and proven in space activities are identified.

ESA

**N89-21949** Centre National d'Etudes Spatiales, Toulouse (France).

**SYSTEM DEPENDABILITY (GENERAL POINTS)**

ALAIN DESROCHES. In its Quality, Components and Technological Analysis p 75-117 Aug. 1988 In FRENCH; ENGLISH summary

Copyright Avail: CEPADUES-Editions, 111 Rue Nicolas-Vauquelin, 31100 Toulouse, France

Risk analysis and its applications to space mission success analysis are reviewed. The probability-gravity curves, decision trees, risk matrices, and other risk analysis methods are examined. Redundant methods, Markov chains, and Monte Carlo simulations are also discussed. French standards and recommendations are mentioned.

ESA

**N89-21951** Centre National d'Etudes Spatiales, Toulouse (France).

**NEW MODELS FOR MECHANICAL RELIABILITY [NOUVEAUX MODELES EN FIABILITE MECANIQUE]**

J. C. LIGERON, R. GORMAND, P. GALLEY (Societe Generale de Travaux Electriques, Puteaux, France), and G. JEANBLANC. In its Quality, Components and Technological Analysis p 137-148 Aug. 1988 In FRENCH

Copyright Avail: CEPADUES-Editions, 111 Rue Nicolas-Vauquelin, 31100 Toulouse, France

The analysis of mechanical systems reliability is approached with the same method applied to electronic systems. International cooperation within the Technical Cooperation Program is described. The mechanical system is decomposed in elementary parts, and the failure probability is a function of the elementary failure probabilities. Data bases and expert systems are being organized to provide the necessary data. Models and expert systems are to be designed for the specific environmental conditions of space missions.

ESA

**N89-21953** Centre National d'Etudes Spatiales, Toulouse (France).

**RISK ANALYSIS IN MANNED SPACE SYSTEM SAFETY**

ALAIN DESROCHES. In its Quality, Components and Technological Analysis p 181-210 Aug. 1988 In FRENCH; ENGLISH summary

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The concepts of risk and safety in manned flight are explored.

developing the notions of risk acceptability, criticality matrix, and conversion of unacceptable to acceptable risks. The probability concept in system reliability analysis is examined, aiming to define overall safety criteria. The global analysis of accident scenarios, the evaluation of hazardous event probabilities, and the safety allocation criteria are presented as advanced risk analysis techniques. ESA

**N89-21970** Centre National d'Etudes Spatiales, Toulouse (France).

#### **RADIATION SENSITIVITY OF MOSFETS**

M. LABRUNEE and P. TASTET. In its Quality, Components and Technological Analysis p 707-753 Aug. 1988 In FRENCH; ENGLISH summary. Copyright Avail: CEPADUES-Editions, 111 Rue Nicolas-Vauquelin, 31100 Toulouse, France

After a review of the characteristics and applications of MOSFET, a radiation test (electron flux exposure) is presented. A study on their heavy ions sensitivity is also included. The design rules for onboard systems using MOSFET are described. ESA

**N89-22627#** Joint Publications Research Service, Arlington, VA. **POWER SUPPLY IN SPACE**

SERGEY DMITRIYEVICH GRISHIN and SERGEY VASILYEVICH CHEKALIN. In its JPRS Report: Science and Technology. USSR: Space p 43-46 17 Aug. 1988 Transl. into ENGLISH from Problemy Osvoeniya Kosmosa (Novoye v Zhizni, Nauke, Tekhnike: Seriya Kosmonavtika, Astronomiya) (Moscow, USSR), no. 1, Jan. 1988 p 27-36

Copyright Avail: NTIS HC A05/MF A01

With the increased complexity of the problems that must be solved and with the longer active service life of spacecraft, the power needs of on-board equipment are growing rapidly. This necessitates the improvement of the present spacecraft power supplies and development of space power engineering. Storage batteries, use of solar energy, and radioisotope and nuclear power units are examined. B.G.

**N89-22643#** Standard Elektrik Lorenz A.G., Stuttgart (Germany, F.R.). Avionics and Aerospace System Group.

#### **GPS TERMINAL: STUDY OF A GPS RECEIVER FOR COLUMBUS PLATFORM ELEMENTS, EXECUTIVE SUMMARY**

Paris, France ESA Jun. 1988 30 p Prepared in cooperation with Bell Telephone Mfg. Co., Antwerp, Belgium and Sener SA, Madrid, Spain (Contract ESTEC-6818/86/NL/PB(SC)) (GPS-REP-SEL-002; ESA-CR(P)-2719; ETN-89-94453) Avail: NTIS HC A03/MF A01

The specification, analysis, design, simulation, and measurements show that the requirements as derived from applications for Columbus Space Station elements and as stated in the Global Positioning System (GPS) terminal performance specification can be met. Modifications in the GPS Core Module and in the GPS Simulator designs existing for ground based applications are necessary to adapt them to the specific space environment. The main modifications with respect to Core Module are: (1) implementation of space qualified parts and materials; (2) replacement of the EPROM by a RAM; (3) development of the GPS Time Generator, the power supply, and the GNC interfaces; (4) design of the housing; (5) adaptation of the signal processor software to the loop parameters required for Columbus applications and to the multi-antenna control requirement; and (6) adaptation of the data processor software to the new initialization procedure, the modified signal acquisition strategy used in the loops, the new ionospheric delay compensation model; the Kalman filtering algorithms required for orbiting receivers, the new calculations necessary for performing range measurement corrections and antenna selections according to the actual station element attitude, and the control from the GNC to perform measurements for differential mode. ESA

**N89-22647#** Erno Raumfahrttechnik G.m.b.H. Bremen (Germany, F.R.).

#### **COLUMBUS MTFF UTILIZATION, PHASE B2X: EXECUTIVE SUMMARY FOR MAIN STUDY**

G. ZELCK Paris, France ESA 25 Nov. 1988 85 p Prepared in cooperation with Fokker BV, Amsterdam, Netherlands and Dornier System GmbH, Friedrichshafen, Fed. Republic of Germany

(Contract ESA-7451/87/F/SC)

(CUT-MBER-800-RP-220; ESA-CR(P)-2744; ETN-89-94466)

Avail: NTIS HC A05/MF A01

Columbus Man-Tended Free Flyer (MTFF) payload operation planning/timelining and the corresponding logistics requirements; and telecommunication during the MTFF operational phase were studied. Critical areas for system development and operation are summarized. ESA

**N89-22774#** Ruhr Univ., Bochum (Germany, F.R.). Arbeitsgruppe Physikalische Chemie der Grenzflächen.

#### **ADSORPTION STUDIES IN THE CRITICAL REGION OF A PURE FLUID. DEVELOPMENT OF AN APPARATUS FOR ADSORPTION MEASUREMENTS UNDER MICROGRAVITY CONDITIONS Final Report**

GERHARD HELMUT FINDENEGG and HANS LEWANDOWSKI Dec. 1987 77 p In ENGLISH and GERMAN Original contains color illustrations

(Contract BMFT-01-QV-070)

(ETN-89-93767) Avail: NTIS HC A05/MF A01

A differential-volumetric measuring apparatus was developed for the determination of the adsorption of supercritical fluids as a function of temperature at constant bulk density. The measurements of thermophysical properties of the microscopic boundary layer at fluid/solid interfaces in the near-critical region are affected by the gravitational field of the Earth that causes a density gradient in the fluid. The developed differential-volumetric technique allows measurements under microgravity conditions on a free-flying space platform like EURECA. The scientific background of these experiments is outlined. Preliminary results for the adsorption of sulfur hexafluoride on graphite and graphitized carbon are presented. ESA

**N89-22801#** Telebit, Copenhagen (Denmark).

#### **STUDY ON COMMUNICATIONS COSTS FOR COLUMBUS UTILIZATION**

SVEND MOLLER NIELSEN and NICOLAJ SORENSEN Paris, France ESA 15 Sep. 1988 77 p

(Contract ESA-7266/87/D/IM)

(REPT-871126/1/FR; ESA-CR(P)-2731; ETN-89-94457)

Copyright Avail: NTIS HC A05/MF A01

On the basis of a hypothetical communications scenario established for cost calculations, the expected communications costs for Columbus utilization in the year 1995 and onwards to the year 2025, are estimated to provide initial considerations for a charging policy in relation to potential Columbus users. A hypothetical sample of five European countries is established, and current telecommunications tariffs for the data, voice, and video communications required for the Columbus utilization in and between these five countries and the USA are identified. Technological, political, and commercial development trends are analyzed as to their likely influences on future telecommunications tariff development. Communications costs for the study period are estimated, assuming telecommunications administrations to be providers of service and considering estimated equipment and operations costs. Alternative communications solutions are indicated. ESA

**N89-22959#** IKO Software Service G.m.b.H., Stuttgart (Germany, F.R.).

#### **THE PROJECT ASKA-SPACE, PHASE 1 Final Report**

GERHARD BAUMANN 1988 54 p In GERMAN; ENGLISH summary Presented at a DFVLR Conference, Cologne, Fed. Republic of Germany, 3 Dec. 1987

(Contract BMFT-01-TB-8503)

(ETN-89-93768) Avail: NTIS HC A04/MF A01

The finite element program ASKA was further developed to fulfill the special requirements of spacecraft structures. The following items received special consideration: data compatibility on the problem definition level; new elements (shell elements and beams); composite elements; thermal and thermo-elastic analysis; sensitivity analysis and optimization; interface programs for the pre and postprocessors and for data base management systems. Studies showed how state of the art analysis methods can be integrated, especially for dynamic analysis. ESA

**N89-23360#** Bundesministerium fuer Forschung und Technologie, Bonn (Germany, F.R.).

**AGREEMENT ON THE INTERNATIONAL SPACE STATION AND COLUMBUS PROGRAM (UEBEREINKOMMEN UEBER DIE INTERNATIONALE RAUMSTATION UND DAS PROGRAMM COLUMBUS)**

29 Sep. 1988 95 p In GERMAN

(REPT-34/88; ETN-89-93985) Avail: NTIS HC A05/MF A01

Articles of the agreement between USA and European member countries, Japan, and Canada for the cooperation on the international space station programs are described. Main phases are: detailed design and development, use and operation of the civil manned space station, personnel, transport, communication, and financial management. Other topics of the agreement concern exchange of goods and scientific data, handling of data in transit, intellectual property regulations, consulting, modification procedure, and withdrawal. ESA

**N89-23509#** Aerospatiale Aquitaine, Saint-Medard en Jalles (France).

**COMPOSITES IN COMPLEX ASSEMBLIES (LES COMPOSITES DANS ASSEMBLAGE COMPLEXE)**

MICHEL VIGNOLLET Paris, France 1988 43 p In FRENCH (REPT-882-430-110; ETN-89-94491) Avail: NTIS HC A03/MF A01

The large diversity of application of composite materials to complex space applications is illustrated describing the design, performance, weight gain, cost, and main mechanical characteristics of many aerospace structural elements actually manufactured. ESA

**N89-23511#** Aerospatiale, Cannes (France).

**THE TWO APPROACHES FOR THE THERMAL CONTROL OF THE COLUMBUS RESOURCE MODULE AND POLAR PLATFORM**

B. POULAIN and S. AUCEL Paris, France 1988 9 p (REPT-882-440-110; ETN-89-94503) Avail: NTIS HC A02/MF A01

The two Columbus architecture systems developed lead to two completely different approaches for the thermal control designs of the Resource Module (RM) and the Polar Platform (PP). The optimized PP thermal control in terms of mass and performance has nevertheless penalties on power budget and servicing mass. The RM thermal control has penalties on mass and performance. Although the two thermal controls are quite different, the selected designs of both are the best compromise which could be achieved at system level. ESA

**N89-23720#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Hauptabteilung Projekte und Mikrogravitation.

**MISSION CONDITIONS AND HARDWARE CONCEPTS (MISSIONSGELEGENHEITEN UND HARDWARE KONZEPTE)**

H. BINNENBRUCK In its Summary of 1st Summer School on Microgravity p 1-23 Jul. 1987 In GERMAN Avail: NTIS HC A09/MF A01

The ORBIS mission conditions and technical concepts are described by charts. Drop tower characteristics, dimensions and structures with ejection mechanisms are depicted. The MIKROBA microgravity balloon experiment technical outlines and payload capacities are specified. For KC-135 jet cargo-type aircraft, flight

characteristics are indicated. The TEXUS (technological experiment under microgravity) mission sequence, profile, and payload concept are summed up. Orbital flight test shuttle use and main objectives; Spacelab system internal accommodation layout; and EURECA system capabilities, mission profile and payload are overviewed. Microgravity missions with national and ESA-NASA participation conditions are summarized. ESA

**N89-23721#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst. fuer Raumsimulation.

**MICROGRAVITY USER SUPPORT CENTER (MUSC) (NUTZERZENTRUM UND NUTZERUNTERSTUETZUNG)**

K. WITTMANN In its Summary of 1st Summer School on Microgravity p 25-37 Jul. 1987 In GERMAN Avail: NTIS HC A09/MF A01

The MUSC supports microgravity experiments concerning materials science, biology, medicine, on EURECA and Spacelab shuttles. Main objectives and technical components are described: information and documentation center with data banks and archives; terrestrial models of space station instruments for experiment preparation; control room for experiment supervision and monitoring; and scientific and technical infrastructure for probe characterization, diagnosis, and data processing during and after the missions. ESA

**N89-23731#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst. fuer Raumsimulation.

**MICROGRAVITY CONDITIONS OF A SPACECRAFT (MIKROGRAVITATIONSBEDINGUNGEN EINES RAUMFAHRZEUGS)**

H. HAMACHER In its Summary of 1st Summer School on Microgravity p 143-167 Jul. 1987 Partly in ENGLISH and GERMAN

Avail: NTIS HC A09/MF A01

Methods for simulation of microgravity are described: parabolic flight, ballistic rockets, aircraft and drop towers. Effectiveness for spacecraft design is evaluated. Atmospheric resistance effects, and tidal and rotation effects are indicated for each method. Sensitivity of experiments to accelerations is discussed. ESA

**N89-23906#** Teldix Luftfahrt-Ausruestungs G.m.b.H., Heidelberg (Germany, F.R.).

**A FAMILY OF BAPTAS FOR GEO AND LEO APPLICATIONS**

W. AUER In NASA, Marshall Space Flight Center, The 23rd Aerospace Mechanisms Symposium p 241-253 Mar. 1989 Avail: NTIS HC A15/MF A02 CSCL 10/1

The application of a Bearing and Power Transfer Assembly (BAPTA) to a Solar Array Drive for communications satellites is presented. The basic principles which were used as guidelines for design and development are developed and the three main subassemblies are described in detail. The results of vibration qualification and thermal vacuum life tests are included. Author

**N89-24335#** European Space Agency, Paris (France).

**INTERNATIONAL SYMPOSIUM ON EUROPE IN SPACE: THE MANNED SPACE SYSTEM**

VALERIE DAVID, ed. and NORMAN LONGDON, ed. Oct. 1988 646 p Partly in ENGLISH and FRENCH Symposium held in Strasbourg, France, 25-29 Apr. 1988; sponsored by BMFT, Bonn, Fed. Republic of Germany, CNES, France, ESA, France, and the Ministero per la Ricerca Scientifica e Tecnologica, Italy (ESA-SP-277; ETN-89-94448) Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

European in-orbit infrastructure elements; Columbus and Hermes; vehicle technology; operation concepts; safety requirements; system operations; attached pressurized module and Man Tended Free Flyers; robotics; user support; and astronauts were discussed. ESA



**N89-24336#** European Space Agency, Paris (France).

# **THE ARIANE 5 DEVELOPMENT PROGRAM**

J. FEUSTEL-BUECHL *In its International Symposium on Europe in Space: The Manned Space System* p 41-47 Oct. 1988  
Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

Competition in the market for commercial launches of satellites is reviewed. The objectives of the Ariane 5 program are summarized: 5800kg payload into GTO; 18,000kg Columbus modules into LEO at 550km, and 12,000kg at 800km; Hermes into transfer orbit (21,000kg); and 98 percent reliability. The launch vehicle, launch complex, and schedule and costs are outlined.

ESA

**N89-24337#** Bundesministerium fuer Forschung und Technologie, Bonn (Germany, F.R.). Aerospace Div.

# **COLUMBUS: THE EUROPEAN CONTRIBUTION TO THE INTERNATIONAL SPACE STATION**

H. STRUB *In ESA, International Symposium on Europe in Space: The Manned Space System* p 49-53 Oct. 1988  
Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The evolution of the Columbus program from Spacelab is traced, and the technical and scientific reasons for the program are mentioned. The International Space Station scenario is outlined, including the cooperation agreements. Ground installations; logistics and transport facilities; and communication systems are described. Interfaces with Ariane 5 and Hermes are indicated. The political importance of Columbus is stressed.

ESA

**N89-24338#** Centre National d'Etudes Spatiales, Toulouse (France).

# **THE HERMES PROGRAM (LE PROGRAMME HERMÈS)**

PH. COUILLARD *In ESA, International Symposium on Europe in Space: The Manned Space System* p 55-58 Oct. 1988 In FRENCH; ENGLISH summary  
Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The decision to initiate the Hermes program is described and the Phase 1 objectives are outlined. These include definition of mission objectives (mainly orbital servicing of Columbus MTFF's); safety analyses; and launch and reentry aspects. Critical technologies which must be developed for Hermes are indicated.

ESA

**N89-24340#** European Space Agency, European Space Operations Center, Darmstadt (Germany, F.R.).

# **THE EUROPEAN IN-ORBIT INFRASTRUCTURE GROUND SEGMENT (LE SEGMENT SOL RELATIF AUX OPERATIONS DE L'INFRASTRUCTURE EN ORBITE EUROPEENNE)**

C. HONVAULT *In its International Symposium on Europe in Space: The Manned Space System* p 63-70 Oct. 1988 In FRENCH

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The methodology used to define the ground segment needed for a European orbital infrastructure is described. Given the decentralized approach adopted, the need to coordinate activities is stressed.

ESA

**N89-24341#** European Space Agency, Paris (France).

# **OVERALL COHERENCE OF THE EUROPEAN PROGRAMS WITHIN A LONG-TERM SPACE POLICY**

G. VANREETH *In its International Symposium on Europe in Space: The Manned Space System* p 71-73 Oct. 1988  
Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The need for coherence between the elements of ESA's long term space programs is stressed. Economic and technical aspects linked to the development of the in-orbit infrastructure, user programs, and ground elements are mentioned.

ESA

**N89-24343#** Aeritalia S.p.A., Turin (Italy). Space Systems Group.

# **PRESSURIZED MODULE ELEMENT FOR MAN'S PRESENCE IN SPACE**

ERNESTO VALLERANI and ELIZABETH MAGGIO *In ESA, International Symposium on Europe in Space: The Manned Space System* p 95-100 Oct. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The external and internal architecture of the Columbus attached pressurized module is described. The Man Tended Free Flyer derivative is presented. Laboratory operation for materials and life sciences in reduced gravity is summarized. The importance of international cooperation and European autonomy is stressed.

ESA

**N89-24344#** Centre National d'Etudes Spatiales, Toulouse (France).

# **FRENCH NATIONAL POLICY ON THE PREPARATION OF COLUMBUS UTILIZATION**

ALAIN ESTERLE and ISAAC REVAH *In ESA, International Symposium on Europe in Space: The Manned Space System* p 101-106 Oct. 1988

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The qualitative and quantitative improvements to be expected from the development of Columbus, Ariane 5, and Hermes are discussed, and the way in which the French Space Agency should adapt its programs to fully exploit their possibilities is considered. Scientific, technical, and industrial implications for the user community are assessed. The need to develop user friendly interfaces is stressed. Preparatory missions for the Columbus program, involving international cooperation, are indicated.

ESA

**N89-24345#** Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.).

# **MTFF USER INTERFACES**

S. GAZEY and K. HUSE *In ESA, International Symposium on Europe in Space: The Manned Space System* p 107-110 Oct. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The utilization interfaces of the Columbus Man Tended Free Flyers (MTFF) are described. The MTFF resources, payload accommodation, and servicing facilities are outlined. The characteristics of the manned life sciences mission involving Hermes are treated. User interfaces are compared with payload requirements as represented by MTFF reference mission and utilization studies. The rack concepts and standard and add-on features are shown.

ESA

**N89-24346#** European Space Agency, Paris (France).

# **HERMES USER INTERFACES**

P. BRUDIEU *In its International Symposium on Europe in Space: The Manned Space System* p 111-115 Oct. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The difficulty of designing Hermes user interfaces before final mission and system decisions are made is discussed. Hermes users are identified (mainly Columbus MTFF). Interfaces with users and payloads during mission preparation is illustrated. Payload/cargo mass and volume requirements are treated. Cargo accommodation is shown. Payload related operations performed by the Hermes crew are considered.

ESA

**N89-24355#** Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.).

# **FUEL CELL DEVELOPMENT FOR HERMES**

H. GEHRKE and U. KNOEBEL *In ESA, International Symposium on Europe in Space: The Manned Space System* p 169-174 Oct. 1988

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Three fuel cell system architectures for the Hermes primary power source were defined. The system has to supply 2 to 6.5 kW and 115 to 90V dc. Weight ratio must be better than 50W/kg, with volume better than 40W/liter. Accumulated operation time is over 4000hr; accumulated storage time 26,000hr. A mobile KOH system with water removal (and cooling) via the KOH loop; a mobile KOH system with water removal via the H<sub>2</sub> loop; and an immobile KOH system with water removal via the H<sub>2</sub> loop were chosen for further investigation. ESA

**N89-24356#** European Space Agency. European Space Operations Center, Darmstadt (Germany, F.R.).

#### FLIGHT OPERATIONS CONCEPT FOR THE EUROPEAN IN-ORBIT INFRASTRUCTURE

W. FRANK and A. SESMA. In *its International Symposium on Europe in Space: The Manned Space System* p 177-183 Oct. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The ESA in-orbit infrastructure ground segment facilities, the structure and functions of operations management, and the communications requirements between facilities and elements in orbit are described. Tactical planning to cope with, e.g., changes in mission objectives is explained. The central mission control center and operations execution management are presented. ESA

**N89-24358#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.).

#### TIMELINING AND OPERATIONS INTEGRATION CONCERNING APM AND MTFF

A. DAVIDSON, K. WEDDE-MUEHLHAUSEN, and K. SCHMIDT. In *ESA, International Symposium on Europe in Space: The Manned Space System* p 191-199 Oct. 1988

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Planning Columbus on-board operations and management of the operational interfaces of the payload ground control team are discussed. Organizational aspects which need to be considered to arrive at a feasible operations structure are assessed, based on Spacelab experience. ESA

#### N89-24359# Compagnia Italiana Servizi Tecnici, Rome. INTEGRATED APPROACH FOR THE LOGISTIC SUPPORT OF THE EUROPEAN IN ORBIT INFRASTRUCTURE FROM THE NINETIES ONWARDS

A. FALCIAI and R. GRAZI. In *ESA, International Symposium on Europe in Space: The Manned Space System* p 201-205 Oct. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

An approach to ensure a cost effective logistics support to ESA's manned space program is outlined. The importance of commonality is stressed. The contribution of logistics to space commercialization is discussed. ESA

**N89-24360#** Aérospatiale, Les Mureaux (France). Div. Systemes Strategiques et Spatiaux.

#### SERVICING OF THE MTFF BY HERMES

P. EYMAR and C. COUGNET (MATRA Espace, Toulouse, France). In *ESA, International Symposium on Europe in Space: The Manned Space System* p 207-214 Oct. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

Servicing tasks which Hermes performs when attached to the Columbus Man Tended Free Flyer (MTFF) are described. The first type of task involves exchange of internal racks and drawers. The most difficult part of this operation involves unloading/loading, transfer, and checkout. Exchange of external Orbital Replacement Units produces problems related to transfers from the pressurized Hermes bay to the unpressurized environment. Configurations to overcome these problems are discussed. ESA

**N89-24361#** Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.).

#### MTFF FLIGHT OPERATIONS PHASES

H. WARTENBERG and H. J. KOOPMANIN. In *ESA, International Symposium on Europe in Space: The Manned Space System* p 215-232 Oct. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

Man Tended Free Flyer (MTFF) pressurized module, resource module, and servicing requirements are outlined, and flight operations are defined. The launch phase, initial activation phase, routine mission operation, and orbital servicing by Hermes are described. The MTFF ground segment infrastructure is presented. Operations planning and management are summarized. ESA

**N89-24362#** Elektronik-System G.m.b.H., Munich (Germany, F.R.).

#### MANNED INTERVENTIONS AT THE MTFF: CREW WORKLOAD ASPECTS

K. BRAMMER and GEORG KAMPFER (Panares, Munich, Germany, F.R.). In *ESA, International Symposium on Europe in Space: The Manned Space System* p 233-237 Oct. 1988

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The scenario of a Hermes visit to a Columbus MTFF and requirements with respect to crew activities for tending the MTFF subsystems and payload were investigated. An intervention concept is derived using a medium degree of automation, with exceptions to cater for optimal workflow, and frequent and time consuming tasks. It is concluded that a 7 day servicing period is required, with most of the difficulties arising from external servicing. The need to make payloads servicing-friendly is stressed. ESA

**N89-24363#** Aeritalia S.p.A., Turin (Italy). Space Systems Group.

#### LOGISTICS ASPECTS OF COLUMBUS SERVICING AT THE SPACE STATION

VINCENZO DEFILIPPIS and LUCIANO BASILE. In *ESA, International Symposium on Europe in Space: The Manned Space System* p 239-244 Oct. 1988

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A common pressurized logistics module (PLM) concept derived from Spacelab/Columbus, and optimized to satisfy International Space Station needs is advocated. A long cycle PLM satisfies requirements for flexible volume to be used for dynamic storage, skipped cycle support, work space, and other applications. Shuttle and expendable transport vehicles are suggested, and the importance of commonality is stressed. ESA

**N89-24367#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.).

#### SYSTEM SAFETY FROM D-MISSIONS TO COLUMBUS

H. SCHUERMANN and W. ZIESMANN. In *ESA, International Symposium on Europe in Space: The Manned Space System* p 275-280 Oct. 1988

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The Spacelab D2 mission safety concept is recalled and development of the concept to meet Columbus requirements is discussed. An example of safety participation during D1 (repairing a mirror heating facility) is described, including ground support. ESA

**N89-24368#** European Space Agency, Paris (France). Columbus System Engineering and Integration.

#### COLUMBUS SAFETY AND RELIABILITY

F. LONGHURST and H. WESSELS. In *its International Symposium on Europe in Space: The Manned Space System* p 281-290 Oct. 1988

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Analyses carried out to ensure Columbus reliability, availability,

and maintainability, and operational and design safety are summarized. Failure modes/effects/criticality is the main qualitative tool used. The main aspects studied are fault tolerance, hazard consequence control, risk minimization, human error effects, restorability, and safe-life design. ESA

**N89-24370#** Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).

**PROTECTION AGAINST IONIZING RADIATION FOR THE HERMES MISSION (PROTECTION CONTRE LES RAYONNEMENTS IONISANTS POUR LES MISSIONS HERMES)** G. MELKONIAN and J. BOURRIEU (Centre National d'Etudes Spatiales, Toulouse, France) In ESA, International Symposium on Europe in Space: The Manned Space System p 303-335 Oct. 1988 In FRENCH; ENGLISH summary (Contract ESTEC-6988/NL/PP(SC))

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

Radiation sources which Hermes crews will be exposed to are described; cosmic rays; trapped particles; and solar radiation. Radiation protection measures based on mission planning; awareness of solar activity; dosimetry; shielding; and biochemical products are considered. ESA

**N89-24372#** European Space Agency. European Space Operations Center, Darmstadt (Germany, F.R.).

**THE ROLE OF THE HERMES FLIGHT CONTROL CENTER IN A TYPICAL HERMES/MTFF SERVICING MISSION**

CHRISTIAN REINHOLD and MARC FRANCOIS (Centre National d'Etudes Spatiales, Toulouse, France) In its International Symposium on Europe in Space: The Manned Space System p 351-359 Oct. 1988

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Nominal prime and support functions of the Hermes flight control center (HFCC) are analyzed in the context of the crew/ground sharing of responsibility for a typical Hermes mission servicing the Columbus MTFF. The support provided by the HFCC includes navigation, medical support, spacecraft monitoring, fault diagnosis, operations replanning, and software uploading. The relationship between the HFCC and the ESA in-orbit infrastructure central mission control center is discussed. Functional requirements of the HFCC concerning real time data control, flight support, and simulation and testing are treated. ESA

**N89-24377#** Aeritalia S.p.A., Turin (Italy). Space Systems Group.

**ATTACHED PRESSURIZED MODULE (APM) CENTER FOR THE COLUMBUS ATTACHED PRESSURIZED MODULE**

GIUSEPPE VIRIGLIO, LUCIANO BATTOCCHIO, CLAUDIO CANU, and GIOVANNI RUM (Piano Spaziale Nazionale, Rome, Italy) In ESA, International Symposium on Europe in Space: The Manned Space System p 389-393 Oct. 1988

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A Columbus attached pressurized module center (APMC) is proposed. The APMC functions include engineering support to operation; payload user engineering support; payload integration; training; and logistics. ESA

**N89-24378#** European Space Agency. European Space Operations Center, Darmstadt (Germany, F.R.).

**EXPERT SYSTEM FOR EUROPEAN SPACE INFRASTRUCTURE**

J. WHEADON In its International Symposium on Europe in Space: The Manned Space System p 395-401 Oct. 1988

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The applicability of expert systems to routine space operations is discussed. A prototype system will be developed to operate with an existing spacecraft control system to act as an operator's assistant in controlling a real time simulation model of the MARECS-B spacecraft. The contribution of expert systems to

enhancing operation reliability and effectiveness will be studied. Knowledge acquisition and representation for the system will be examined. The possibility of transferring ground based operations onto autonomous spaceborne systems will be investigated. The minimum that the expert is expected to achieve is recognition of operating states and diagnosis of unit-level failures and anomalies in spacecraft subsystems. ESA

**N89-24381#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.).

**EXPERIMENTATION IN THE MANNED FREE FLYER (MTFF)**

H. BAUER and D. HEYLAND In ESA, International Symposium on Europe in Space: The Manned Space System p 415-427 Oct. 1988

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Scenarios and constraints for experiments using the Columbus MTFF are outlined. Robotization and automation aspects are discussed. Experimentation on MTFF is comparable to a combination of EURECA (automated mode) and Spacelab (manned activities). Utilization of a full integrated MTFF depends on the transport capacity of Hermes. It is argued that the present Hermes design excludes an optimal use of the MTFF since the transport of consumables/samples from running experiments prevents Hermes accommodating new facilities. The baseline MTFF mission consists of payloads for metallurgy, crystallization, and biology investigations. ESA

**N89-24390#** Fokker B.V., Amsterdam (Netherlands).

**THE HERMES ROBOT ARM (HERA)**

R. HAMANN, C. BLAAS, and R. H. BENTALL (European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) In ESA, International Symposium on Europe in Space: The Manned Space System p 493-501 Oct. 1988

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The orbital servicing functions provided by the Hermes robot arm (HERA) are described. The HERA design and verification procedures are reviewed. The HERA functions include capture of a free flying satellite; berthing, unberthing, and reberthing; payload transfer and release; ORU exchange; inspection; tool manipulation; and EVA support. ESA

**N89-24392#** LABEN Space Instrumentation and Systems, Milan (Italy). Advanced Research and Development Dept.

**ADVANCED MMI AND IMAGE HANDLING TO SUPPORT CREW ACTIVITIES**

R. CORTINOVIS, B. BARNI, and R. PERSICO In ESA, International Symposium on Europe in Space: The Manned Space System p 509-514 Oct. 1988

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A concept for a crew workstation, focusing on man-machine interface (MMI) aspects related to the integrated handling of text, graphics, and visual information is presented. Window and overlay management methods, and image processing techniques for picture quality enhancement are discussed. ESA

**N89-24394#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.).

**THE MICROGRAVITY USER SUPPORT CENTER (MUSC)**

K. WITTMANN, H. P. SCHMIDT, D. PADEKEN, B. HILDMANN, E. BENNETT, and B. FEUERBACHER In ESA, International Symposium on Europe in Space: The Manned Space System p 525-530 Oct. 1988

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Function and objectives of user support in the ESA Microgravity User Support Center (MUSC) are summarized. The MUSC functions include user information services; ground support; mission support; and scientific support. ESA



**N89-24395#** Naples Univ. (Italy). Inst. of Aerodynamics.

**MARS MICROGRAVITY ADVANCED RESEARCH AND SUPPORT CENTER**

LUIGI G. NAPOLITANO In ESA, International Symposium on Europe in Space: The Manned Space System p 531-540 Oct. 1988

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The Microgravity Advanced Research and Support (MARS) center is presented. Its role in the Columbus program is described. The functions of the MARS center include basic research; microgravity experimentation; user support; technology assessment; and support to space agencies. Operational and program implementation aspects are summarized. ESA

**N89-24399#** Aeritalia S.p.A., Turin (Italy). Space Systems Group.

**THE UTILIZATION OF THE EUROPEAN PRESSURIZED MODULE FOR NON-EUROPEAN EXPERIMENTS**

G. OELKER, M. S. LAVITOLA, and A. ALLEGRA In ESA, International Symposium on Europe in Space: The Manned Space System p 573-575 Oct. 1988

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Physical accommodation of non European experiments in the European pressurized module on the International Space station, and ground processing of the data are considered. The need for commonality is stressed, and it is suggested that operations requiring very strict specifications and highly constraining procedures be confined to satellites. ESA

**N89-24401#** European Space Agency, Paris (France). Directorate of Space Station and Platforms.

**HERMES CREW ROLE**

CLAUDE NICOLLIER In its International Symposium on Europe in Space: The Manned Space System p 591-593 Oct. 1988

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The role of the crew on Hermes is outlined, and the optimal mix of crew and automatic systems is considered. Tasks during each flight phase, including orbital servicing of Columbus are listed. It is stressed that manual control should also be possible for each automatic phase. The small size of the crew makes extensive cross training necessary. ESA

**N89-24403#** European Space Agency, Paris (France).

**THE ASTRONAUT'S FUNCTIONS ABOARD COLUMBUS**

U. MERBOLD In its International Symposium on Europe in Space: The Manned Space System p 605-608 Oct. 1988

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The role of Columbus astronauts in system operations; payload operations; and assembling is outlined. Operations on the attached pressurized module and MTFF are described. ESA

**N89-24625#** National Aerospace Lab., Tokyo (Japan).

**ANALYSIS OF ADAPTIVE PLANAR TRUSS STRUCTURES**

Aug. 1988 26 p In JAPANESE; ENGLISH summary (NAL-TR-888; ISSN-0389-4010) Avail: NTIS HC A03/MF A01

The structural concept of adaptive planar truss structures is evaluated from the viewpoints of both geometrical adaptivity and dynamic characteristics, and an attempt is made to clarify the basic idea concerning what kind of adaptive planar truss structures are desirable to realize the concept in real structure hardware. The basic octet elements for planar truss structures and their various modified configurations, including cube elements, are arranged for the idea of adaptive elements. Two ways of obtaining an appropriate curved surface from a flat truss structure, that is, the bending concept and the shear concept, are related to the adaptive elements. Two ways of obtaining an appropriate curved surface from a flat truss structure, that is, the bending concept and the shear concept, are related to the adaptive elements. Stiffness properties of some basic adaptive planar truss structures,

which consist of cube elements, in a comparatively moderate or small scale are investigated through vibration analysis using the Finite Element Method (FEM). Vibration characteristics for various configurations, such as flat, parabolic cylinder, elliptic paraboloid and hyperbolic paraboloid are shown. Author

**N89-25556#** Lockheed Engineering and Sciences Co., Washington, DC.

**USSR SPACE LIFE SCIENCES DIGEST. INDEX TO ISSUES 15-20**

LYDIA RAZRAN HOOKE, ed. Washington NASA Apr. 1989 151 p

(Contract NASW-4292)

(NASA-CR-3922(25); NAS 1.263922(25)) Avail: NTIS HC A08/MF A01 CSCL 06/3

This bibliography provides an index to issues 15 through 20 of the USSR Space Life Sciences Digest. There are two sections. The first section lists bibliographic citations of abstracts in these issues, grouped by topic area categories. The second section provides a key word index for the same abstracts. The topic categories include exobiology, space medicine and psychology, human performance and man-machine systems, various life/body systems, human behavior and adaptation, biospherics, and others. Author

**N89-26585#** Centre d'Etudes et de Recherches, Toulouse (France). Groupement d'Intelligence Artificielle.

**MISSION SCHEDULING**

CHRISTINE GASPIN In NASA, Goddard Space Flight Center, The 1989 Goddard Conference on Space Applications of Artificial Intelligence p 75-86 Apr. 1989

Avail: NTIS HC A17/MF A03 CSCL 09/2

How a neural network can work, compared to a hybrid system based on an operations research and artificial intelligence approach, is investigated through a mission scheduling problem. The characteristic features of each system are discussed. Author

**N89-26880#** Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.).

**COLUMBUS LOGISTICS PROGRAM**

MIKE C. ATTWOOD 1988 11 p Previously announced in IAA as A89-18314

(MBB-UO-0039/88-PUB; ETN-89-94617) Avail: NTIS HC A03/MF A01

The overall logistics scenario which reflects the design configurations and operational concepts as derived from the Columbus phase B activities and results of considerations of coherence with other European space elements, (e.g., Hermes), is described. The required resupply infrastructure, covering the range from provisions for off-line repair of units at a manufacturer's site via ground/orbit transport to on-orbit storage, until utilization in a servicing activity, are identified. ESA

**N89-27707#** Deutsche Gesellschaft fuer Luft- und Raumfahrt, Bonn (Germany, F.R.).

**DGLR/AIAA/JSASS 20TH INTERNATIONAL ELECTRIC PROPULSION CONFERENCE: PROCEEDINGS**

1988 741 p Conference held in Garmisch-Partenkirchen, Fed. Republic of Germany, 3-6 Oct. 1988 Sponsored by the BMFT, Bonn, Fed. Republic of Germany Original contains color illustrations

(DGLR-PAPER-88-02; ISBN-3-92-2010-40-7; ETN-89-95006)

Avail: NTIS HC A99/MF E03

Topics discussed at this conference include: magnetoplasma-dynamic thrusters; power sources and interactions; field emission electric propulsion; auxiliary propulsion; power conditioning and control; ion thrusters; missions; electrode processes; plasma and plume phenomena; microwave devices; s/c jet engines; thruster-spacecraft interactions; and nonpropulsive applications.

ESA

**N89-27750#** Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Space Communications and Propulsion Systems Div.

**ELECTRICAL TRANSFER VEHICLE ANALYSIS FOR FUTURE SPACE OPERATIONS (MESCATS)**

W. KLEINAU, D. E. KOELLE, and W. MUELLER. In DGLR, DGLR/AIAA/JSASS 20th International Electric Propulsion Conference: Proceedings p 383-390. 1988

Avail: NTIS HC A99/MF E03

A modular orbital transfer vehicle for scientific and cargo transportation missions called MESCATS was investigated, in particular for advanced transportations between operational bases as well in a geostationary orbit such as a lunar orbit. A cluster of electrical ion-thrusters (RIT 35) was considered as the main propulsion system. The MESCATS is, due to its high specific impulse (up to 38,000 Nsec/kg), an interesting candidate providing not only high delta velocity increments (relevant in particular for scientific missions), but is especially economic for cargo missions (Earth/Moon). It appears feasible to develop an E-OTV like MESCATS which could meet a wide range of operational requirements (such as payload mass, orbital transfer time, velocity increment) with key elements assumed to be available in Europe in the medium term. ESA

**N89-28214#** European Space Agency, Paris (France). **THIRD EUROPEAN SYMPOSIUM ON SPACE THERMAL CONTROL AND LIFE SUPPORT SYSTEMS**

T. DUC GUYENNE, ed. and J. HUNT, ed. Dec. 1988. 629 p. Symposium held in Noordwijk, Netherlands, 3-5 Oct. 1988 (ESA-SP-286; ISSN-0379-6566; ETN-89-95012). Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

Environmental control and life support systems; heat transport systems; orbital systems thermal control; atmosphere management; EVA; analysis methods; satellite thermal control; liquid management and habitability; cryogenics; in-orbit performance and testing; thermal control technology; and reentry and thermal protection systems were discussed.

ESA

**N89-28217#** Aerospatiale Usines de Toulouse (France). **THE HERMES SPACEPLANE PROGRAM: STATUS REPORT ON THE THERMAL CONTROL, ENVIRONMENT CONTROL AND LIFE SUPPORT ACTIVITIES**

H. LACAZE, P. BISIAUX, and C. RODIERE. In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 25-36. Dec. 1988

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The status of the Hermes, the thermal protection subsystem, thermal control subsystem, and environmental control and life support subsystem is outlined. Each one contributes to the thermal control of some part of the vehicle and is therefore influenced by the two others. Due to severe constraints coming from the launcher performances, the Hermes mass budget is critical and renders necessary elaborate design studies and use of advanced techniques for most component parts. ESA

**N89-28218#** Domier System G.m.b.H., Friedrichshafen (Germany, F.R.).

**EUROPEAN LIFE SUPPORT SYSTEMS FOR SPACE APPLICATIONS**

H. PREISS. In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 39-44. Dec. 1988

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The environmental control and life support systems (ECLSS) for Columbus and Hermes are described, and the ECLSS requirements for European missions to Mars, the Moon, and an LEO station are outlined. It is argued that to meet these demands, international cooperation is necessary. ESA

**N89-28223#** MATRA Espace, Paris-Velizy (France).

**POSSIBLE USE OF A GAS MONITORING SYSTEM IN SPACE RESPIROMETRY STUDIES**

C. LASSEUR, C. CHIPPAUX, M. ANDRE, F. X. COTE, and J. MASSIMINO (Commissariat à l'Energie Atomique, Saint-Paul-les-Durance, France). In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 69-72. Dec. 1988

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The C23A system (automatic culture chambers in artificial atmosphere) was used in respiratory studies on a small animal, Triturus Walt II. The multiplexed analyzers allow use of the same analyzer for several different applications, e.g., respirometry, or atmosphere. This method permits to decrease weight and reduce the number of gas calibrations. Similarly the design of the computing system anticipates the full separation between automation in space and control-command on ground. ESA

**N89-28224#** Domier System G.m.b.H., Friedrichshafen (Germany, F.R.).

**TWO-PHASE HEAT TRANSPORT SYSTEMS: CRITICAL COMPONENTS**

H. KREIB and R. SIEPMANN. In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 75-82. Dec. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

Within the preparatory support technology program for COLUMBUS a mechanically pumped two-phase heat transport system is developed. A preparatory study recommended system based on a parallel arrangement of evaporator cold plates and heat exchangers, condenser units, and a conventional mechanical pump. Important characteristics of this system include the controlled flooding of the condensers with liquid to achieve temperature control and the ability to use the evaporators also as condensers to permit heat load sharing between payload elements. In order to meet Columbus-requirements the system is specified to work at a maximum heat load of 10 to 20 kW at a nominal temperature of 20 C. The working medium is freon R 114. The design of the overall system, the breadboard development of the critical components, and the planned test-bed verification are outlined.

ESA

**N89-28226#** Entwicklungsring Nord, Bremen (Germany, F.R.).

**DESIGN AND TEST OF A TWO-PHASE COLDPLATE**

R. MUELLER. In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 89-95. Dec. 1988

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The design and the results of a performance test for a two phase cold plate are presented. The cold plate consists of 7 parallel aluminum evaporator tubes and a 50 x 50 cm mounting plate. The evaporator tubes are equipped with capillary circumferential grooves and an internal structure to separate liquid and vapor. The cold plate is suitable for application in mechanically, as well as capillary pumped loops. In the test the heat transport limit of the evaporator tubes, i.e., the dryout of their circumferential grooves, was evaluated. The test was conducted in the mechanically pumped mode using ammonia as a working fluid. It demonstrates the feasibility of the selected design of the cold plate evaporator tubes. Heat flux limits ranging from 2.4 and 10.7 W/sq cm and heat transfer coefficients between 0.14 and 1.35 W/sq cm-K were measured for the different evaporator tubes.

ESA

**N89-28230#** National Aerospace Lab., Emmeloord (Netherlands). Space Div.

**DEVELOPMENT OF A SENSOR FOR HIGH-QUALITY TWO-PHASE FLOW**

A. A. M. DELIL and J. F. HEEMSKERK In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 113-123 Dec. 1988 Sponsored in part by the Netherlands Agency for Aerospace Programs  
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Based on a tradeoff of quality monitoring concepts, a dedicated quality sensor for two phase mixtures was developed, based on the axial capacitance principle. Its theoretically demonstrated feasibility as quality and wetting sensor was experimentally confirmed by experiments using liquid layer simulating plastic sheets and annular air/liquid flow. Experiments in a two-phase freon test loop show the sensor to be an accurate, fast responding, sensitive instrument. It was accepted for further development as a component of the two-phase heat transport system developed by the European Space Agency. Performance figures, obtained by calibrations in a freon 114 loop, are given. Recommendations for future work and applications are indicated. ESA

**N89-28231#** Aerospatiale, Cannes (France).  
**THE TWO APPROACHES FOR THE THERMAL CONTROL OF THE COLUMBUS RESOURCE MODULE AND POLAR PLATFORM**

B. POULAIN and S. AUCEL In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 127-134 Dec. 1988 Previously announced as N89-23511  
Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

The impact of the requirements of the Columbus program such as long life time and servicing on system architecture and subsequently on thermal control systems (TCS) design is discussed. Based on these requirements two completely different approaches were selected for polar platform (PPF) and resources module (RM) architectures. The system architecture/TCS approach used for the PPF (individual TCS of ORU) led to an optimized TCS in terms of mass and performance (i.e., launch cost) having nevertheless certain penalties: on power budget (improvements are possible); and on servicing mass (acceptable). The RM system architecture/TCS approach (centralized TCS) is optimized with respect to servicing operations and power budget but has penalties on TCS mass and performance. These penalties are compensated by global savings at MTFF level. One of the prime drivers leading to the difference between the two approaches is the use of Hermes as servicing vehicle for RM and not for PPF (additional constraint on RM). Although the TCS performances are quite different, the selected designs of both spacecraft are the best compromises which could be achieved at system level. ESA

**N89-28232#** Erno Raumfahrttechnik G.m.b.H. Bremen (Germany, F.R.).

**REDUNDANCY CONCEPT FOR THE COLUMBUS MAN-TENDED FREE-FLYER THERMAL CONTROL SYSTEM**  
B. BEHRENS, C. BUNKENBORG, W.-D. EBELING, and U. LAUX In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 135-140 Dec. 1988  
Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

The Columbus Man-Tended Free Flyer (MTFF) thermal control system (TCS) is described. The redundancy philosophy for TCS is discussed and the resulting thermal control concept presented. Effects of the failure tolerance requirements on the overall MTFF thermal control architecture as well as the arrangement of subsystem units within the MTFF for thermal control reasons is considered. Reliability analyses are outlined. For operating the MTFF at a required reliability level of 0.93 for nominal payload support for 180 days, the items aboard are classified in three criticality categories. Therefore various required failure tolerances have to be provided by an appropriate redundancy concept for each of these criticality categories. ESA

**N89-28233#** Aeritalia S.p.A., Turin (Italy).  
**THERMAL CONTROL OF COLUMBUS PRESSURIZED MODULES**

S. DO'CE, M. TRICHILO, and F. BERARDI In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 141-147 Dec. 1988  
Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

The thermal control architecture of Columbus Pressurized Modules (PM); tradeoffs and design activities performed up to the present phase CD; and the baseline design solutions at loop and at component level are discussed. Active thermal control architecture consists of: module internal water loops collecting heat from directly interfacing P/L's and S/S's, avionics and cabin air loops; space station external freon loop (PM2 only) providing removal and transportation of water loop heat loads to the heat rejection system; based thermal bus providing removal and rejection of docked element water loops heat loads; and loop control and monitoring functions provided by modulating pumps and valves, temperature, pressure, and flow sensors interfacing with an intelligent control unit. Passive thermal control architecture consists of: MLI to insulate the modules and limit heat leaks, gains; coatings to provide the required thermo-optical properties; and internal insulation to avoid condensation. ESA

**N89-28236#** Contraves Corp., Zurich (Switzerland). Space Dept.

**THE SPACE-RIGIDISED THERMAL SHIELD FOR THE ESA FAR-INFRARED SPACE TELESCOPE (FIRST)**

M. C. BERNASCONI and S. KOESE In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 165-173 Dec. 1988  
(Contract ESTEC-6324/85/NL/PB(SC))  
Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

Results of the feasibility investigation of an inflatable space rigidized thermal shield for the FIRST-mission are presented. Possible ISRS-shield configurations were surveyed. The configuration study confirms the use of a truncated cylinder shield concept. Stowage patterns and deployment sequences are discussed, leading to an overview of the rigidization aspects. For a proper cure, the rigidizable structure must be heated to a predefined temperature by proper orientation with respect to the Sun. The cure analysis shows that the structure can be cured within 9 hrs, using an external gaseous catalyst. Evaluation of the thermal efficiency shows that the thermal requirements can be satisfied with a 6-layer MLI blanket. The structural analysis shows that the shield meets the 2-Hz stiffness requirement. ESA

**N89-28241#** Dornier System G.m.b.H., Friedrichshafen (Germany, F.R.).

**THE ATMOSPHERE PRESSURE CONTROL SECTION OF THE HERMES ECLSS**

G. HAUSER In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 199-204 Dec. 1988  
Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

The Atmosphere Pressure and Control Section (APCS) is part of the Hermes Environmental Control and Life Support Subsystem (ECLSS), which has to provide a safe and habitable environment for the crew. The APCS maintains the cabin total pressure and oxygen partial pressure in the specified limits, and supplies gas to several users, e.g., EVA suits, oxygen masks, docked MTFF. It has the capability to restore the atmosphere after depressurization of the airlock at the end of EVA as well as after evacuation of the total habitable volume after fire/contamination. Calculated performance data are presented. The location of all APCS-assemblies within the different Hermes volumes and



conceptual details such as redundancy and safety provisions are shown. ESA

**N89-28242#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Space Station Program Office.

**COME TO FLIGHT RULES: RATIONALE ON ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEMS**

H. BAUER. In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 205-208 Dec. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

Critical aspects of the Hermes-MTFF system flight rule definition are discussed. The most constraining life support system is the cabin pressure integrity, the O<sub>2</sub> and CO<sub>2</sub> concentration. It starts with an emergency landing requirement abort once around, or if it is worse with a transatlantic landing or even with a return to landing site. Loss of two H<sub>2</sub>O loops within the air revitalization system requires also an abort once around. For all other failures a work-around solution according operational flight rules can be found. Failure in the flash evaporator system may not cause an emergency landing, but evaluating existing systems and relevant flight rules can keep the crew busy in solving the problems and to continue the flight with constraints. ESA

**N89-28249#** MATRA Espace, Toulouse (France). **IMPROVED RAY TRACING TECHNIQUE FOR RADIATIVE HEAT TRANSFER MODELLING**

C. KOECK. In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 255-260 Dec. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

The implementation of an optimized ray-tracing technique in a thermal radiation software based on Monte-Carlo gave an efficient tool to compute radiative exchange factors and external heat fluxes. The software presents the advantages of the Monte-Carlo method: better physical modeling, simplicity of use, without its usual drawback: computer run time. As an indication, computation of view-factors within an enclosure of hundred surfaces can be 100 times faster than when using the double summation method of VWHEAT. Features such as surface specularly or transparency are accounted for in the simulation. ESA

**N89-28253#** Danish Research Center for Applied Electronics, Hørsholm.

**EFFICIENT IMPLEMENTATION OF A DESCRIPTION LANGUAGE FOR THERMAL SIMULATORS**

P. STANGERUP. In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 261-267 Dec. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

It is shown which requirements should be made to the description language of a thermal simulator and how this language is implemented. It is demonstrated that the only thermal components required are: conductors, capacitors, source of heat flow rate, and source of applied temperature. This is true if all component values in the description language can be expressed as arbitrary functions of system variables. The ideas which ensure a high degree of generality are implemented in the ESACAP program, available on IBM compatible PC's. ESA

**N89-28278#** European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).

**THERMAL SOFTWARE DEVELOPMENTS AT ESTEC**

C. STROOM. In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 463-467 Dec. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div.,

ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

The major software activities of the Thermal Control and Life Support Division of ESTEC are reviewed. Ongoing activities are listed and the outline for future activities is given. The role of ESTEC in the support and maintenance of the distributed software is emphasized. ESA

**N89-28282#** Aerospatiale, Cannes (France). Space and Strategic Systems Div.

**THE FLUIDNET DEVELOPMENT AND APPLICATION TO PRELIMINARY SIZING OF FLUID-LOOP SYSTEMS**

S. ANDRE, J. N. CHELOTTI, J. F. GORY, and T. LAFON (Centre National d'Etudes Spatiales, Toulouse, France). In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 489-495 Dec. 1988 Previously announced as N89-23845

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

Fluidnet is a computer program for preliminary sizing of fluid loop networks used in space thermal control systems. Fluidnet is an interactive application, whose main features are: easy implementation, rapidity, portability, flexible architecture. It is complementary with design tools like FLUENT and FHTS (fluid loop analysis extensions from SINDA and ESATAN). The current version is applied to thermal and hydraulic analysis of single phase fluid loops in steady state. ESA

**N89-28283#** Dornier System G.m.b.H., Friedrichshafen (Germany, F.R.).

**EVOLUTION OF THERMAL ANALYSIS METHODS TOWARDS INTEGRATED SYSTEM PERFORMANCE SIMULATION**

M. ROTHMEYER and W. SCHWARZOTT. In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 497-505 Dec. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

A loose integration of thermal analysis tools into a common software system is described. The requirements for thermal modeling within future space projects and the software tools which are being developed are listed. Using the thermal simulation of the habitable volumes of Hermes as an example, the benefits of integrated thermal models are discussed. ESA

**N89-28294#** Dornier System G.m.b.H., Friedrichshafen (Germany, F.R.).

**ECLS SIMULATION PROGRAM**

G. KIRSCHNER. In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 507-511 Dec. 1988

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Showing the importance and advantages of an integrated simulation, models for EVA, Hermes and Columbus ECLS systems have to be developed. Using modular program technique the same subroutines for equal functions can be used for the different simulation models. The tasks of the single modules are described and it is shown how existing commercial programs are used for in- and out-put, documentation, and data representation. An example from already programmed modules and an outlook for further program development is given. ESA

**N89-28561#** Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.).

**KEY STRUCTURES MECHANICAL ISSUES OF THE EUROPEAN SPACE STATION AND PLATFORM PROGRAM COLUMBUS**

S. GAZEY and E. WINKELHOFF. 1988 10 p Presented at the Spacecraft Structures and Mechanical Testing Conference,

Noordwijk, Netherlands, 19-21 Oct. 1988

(MBB-UD-0041-88-PUB; OTN-010456; ETN-89-95334) Avail: NTIS HC A02/MF A01

The main technical features of the Columbus space segment are discussed. The attached pressurized module (APM), integrated into NASA's Space Station Freedom; the man tended free flyer (MTFF) - Europe's first step into autonomy in space; and the polar platform (PPF), are described. The requirements for long life in orbit operation are considered: more realistic APM design loads must be determined to define maximum allowable launch mass; Columbus flight configuration responses to in-orbit operation loads must be determined by advanced nonlinear analysis tools; protection of the crew and subsystems against meteoroids and space debris are necessary, as well as analytical tools and test facilities to verify the required probability of nonpenetration of the modules; and repair procedures and maintenance tools have to be developed to ensure in-orbit structural integrity. ESA

**N89-28563#** Sira Inst. Ltd., Chislehurst (England).

**A MEDIUM RESOLUTION IMAGING SPECTROMETER FOR THE EUROPEAN POLAR ORBITING PLATFORM**

M. A. CUTTER, D. R. LOBB, Y. RAMON, G. RATIER, and J. L. BEZY (European Space Agency, European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) 1989 10 p (ETN-89-95235) Avail: NTIS HC A02/MF A01

The design for the Medium Resolution Imaging Spectrometer (MERIS), proposed as a candidate core instrument for the European polar platform scheduled for launch in 1997, is described. The instrument has a spectral range of 400 to 1050 nm, a swath width of 1500 km, spectral resolution of 1.25 nm, and spatial resolution of 260 m. Spectral bands, and spectral and spatial resolution, can be reprogrammed in orbit. The instrument has applications in the fields of marine, land and atmospheric research. MERIS provides high radiometric performance at medium spatial resolution, which is appropriate primarily for oceanographic measurements. The instrument also offers the capability of monitoring high albedo targets which are of value in remote sensing of ice, land and coastal regions. ESA

**N89-29410#** Joint Publications Research Service, Arlington, VA. **US COMPANY TO FLY BIOCRYSTAL EXPERIMENT ON MIR STATION Abstract Only**

YU. SUBBOTIN In its JPRS Report: Science and Technology. USSR: Space p 31 18 Jan. 1989 Transl. into ENGLISH from Sovetskaya Rossiya (Moscow, USSR), 12 Apr. 1988 p 3 Copyright Avail: NTIS HC A04/MF A01

For the first time, the U.S. Government has authorized a private American company to conduct scientific research on board a Soviet space station. A commercial agreement has been reached between this firm, Payload Systems Incorporated, and the USSR Main Administration for Development and Use of Space Technology for the Economy and Scientific Research (Gleukosmos). This agreement calls for conducting a series of six experiments, in the course of which an American unit for growing biocrystals will be delivered to the Mir station by a Progress transport spaceship. This unit will operate on the station in conditions of prolonged weightlessness. Soviet cosmonauts will return it to Earth when the next experiment is completed. The product which is obtained can ultimately be utilized for development of new drugs. Author

**N89-29439#** European Space Agency, European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).

**ARIANE TECHNOLOGY EXPERIMENT PLATFORM (ARTEP)**

M. TRISCHBERGER and B. LACOSTE (European Space Agency, Paris, France) In ESA, First European Workshop on Flight Opportunities for Small Payloads p 43-46 May 1989 Copyright Avail: NTIS HC A09/MF A02; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 40 Dutch guilders

The concept and planning information for the ARTEP, aimed to provide a European secondary payload capability, using the

Ariane 4 as a carrier vehicle. ARTEP is a free flying platform, which operates up to 10 days in the Geosynchronous transfer orbit. ESA

**N89-29473#** National Space Development Agency, Ibaraki (Japan). System Engineering Dept.

**TECHNOLOGY REQUIRED BY THE SPACE PLATFORM**

NORIKAZU HARA, MASASNOZRI HOMMA, TAKASHI HAMASAKI, and RYOICHI IMAI 18 Nov. 1987 12 p In JAPANESE; ENGLISH summary Presented at NASDA's 19th Technical Session, Ibaraki, Japan, 18 Nov. 1987 (NASDA-CP-05-11; JTN-88-80031) Avail: NTIS HC A03/MF A01

A space platform is a type of spacecraft that would be operated by receiving a number of services in space. These services would include exchanging instruments and materials, repair, refueling, inspection and adjustment, transportation and assembly. The space platform will require various technologies. The development of this large, multi-purpose spacecraft would require sophisticated technologies to achieve a high degree of flexibility in operation and mission requirement. These technologies would include system modularization, replaceable units, rendezvous and docking (RVD) technology, guidance and control of a large structure, large capacity communication and data handling through data relay satellites, a structure and mechanism for adapting the module and unit concept, a bi-phase loop for thermal control, propulsion technology with refueling and automatic (and autonomous) operation technology. NASDA

**N89-29474#** National Space Development Agency, Tokyo (Japan). Space Environment Utilization Promotion Office.

**OPERATIONS CONCEPT OF JAPANESE EXPERIMENT MODULE (JEM)**

YASUSHI HORIKAWA 9 Jun. 1988 30 p In JAPANESE; ENGLISH summary Presented at NASDA's 4th Technical Symposium, Tokyo, Japan, 9 Jun. 1988 (NASDA-CP-06-6; JTN-88-80054) Avail: NTIS HC A03/MF A01

The Space Station Program was initiated by the U.S. National Aeronautics and Space Administration (NASA) with the participation of the European Space Agency (ESA), Canada, and Japan. The Space Station Core System is provided by NASA. The Attached Pressurized Modules (APM) are provided by ESA. The Japanese Experiment Module (JEM) is provided by Japan. A manipulator system called Mobile Service Center is provided by Canada. From 1986 to 1987, the partners conducted preliminary design of the space station. In order to start the Space Station Program, each partner has agreed to cooperate with NASA. This agreement is intended to cover all items, not only for the development of the space station but also for its operation and use. The space station basic operations and utilization concepts are discussed and coordinated among the partners internationally. The station's operational organization, management strategy, international responsibility, operations cost, etc. are also coordinated among the partners. Based on this coordination, studies on the systems and facilities necessary for operating the space station are conducted. This paper deals with the preliminary study results of the operations concept, emphasizing the operation of the JEM. NASDA

**N89-29632#** European Space Agency, European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).

**THE IOC EXPERIMENT FOR DATA RELAY FROM EURECA VIA OLYMPUS**

S. E. D'NWIIDY and N. NEALE In its Olympus Utilization Conference p 187-190 May 1989

Copyright Avail: NTIS HC A23/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The ESA Inter-Orbit Communications (IOC) experiment designed to relay data between a space terminal mounted on the European Retrieval Carrier (Eureca) in a 500 km altitude orbit and an earth terminal via the 20/30 GHz communications payload of Olympus is described. ESA

**N85-29772#** National Space Development Agency, Tokyo (Japan). Reliability Assurance Dept.

# **QUALITY ASSURANCE OF PARTS FOR SPACE USE**

SUMIO MATSUDA 9 Jun. 1988 30 p In JAPANESE; ENGLISH summary Presented at NASDA's 4th Technical Symposium, Tokyo, Japan, 9 Jun. 1988

(NASDA-CF-06-3; JTN-88-80051) Avail: NTIS HC A03/MF A01

The failure of parts in space systems was recently discovered which has made a serious impact on projects of the National Space Development Agency of Japan (NASDA). These failures triggered discussion about quality assurance of parts for space use. Parts problems of space systems in development and in orbit, requirements of space parts, situations of parts in system designs, and quality assurance of parts are discussed. A summary of TEDA (Technical Data Acquisition Equipment) on ETS-5 (Engineering Test Satellite-5) and a summary of studies of parts development engineering in the Tsukuba Space Center are introduced. Their relationship with quality assurance of parts is described. NASDA

## 19

### **SUPPORT SPACECRAFT**

Includes design, analysis, requirements, trade studies and simulations of Space Station support spacecraft including the orbital transfer vehicle (OTV) and the orbital maneuvering vehicle (OMV).

**N89-22338#** National Aeronautics and Space Administration, Washington, DC.

# **NASA GROUND COMMUNICATIONS**

JOHN ROEDER In NASA, Goddard Space Flight Center, Proceedings of the Scientific Data Compression Workshop p 163-180 Feb. 1989

Avail: NTIS HC A19/MF A03 CSCL 17/2

As part of the Communications Requirements and Constraints, NASA's two major Ground Data Networks were briefly described. The NASA Communication Network, called NASCOM, is the worldwide operational telecommunications system which interconnects as the tracking and telemetry acquisition sites, launch areas, mission and project control centers, data capture facilities, and network control centers in support of space flight. For the Space Station era, NASCOM plans are set for higher data rate service utilizing data packet switched technology. Increased use of fiber optics is expected in a much more diverse network topology. The second major ground network, the Program Support Communications Network (PSCN), interconnects all NASA Centers and NASA contractor locations for intercenter non-operation communications. The primary functions are to transport voice, video, data and facsimile information for intercenter coordination, and to provide user access to space science and applications data bases. For the Space Station era, PSCN plans address the significant increase in forecast requirements for science data distribution and access to the Numerical Aerodynamics Simulator, and increased use of the Video Teleconference System. Author

**N89-24050#** Aerospatiale, Paris (France).

# **THE ROLE OF PILOT AND AUTOMATIC ONBOARD SYSTEMS IN FUTURE RENDEZVOUS AND DOCKING OPERATIONS**

W. FEHSE, A. TOBIAS, A. GETZSCHMANN, M. CALDICHOURY, P. MAUTE, and M. ATTANASIO (Aerospatiale, Cannes La Bocca, France) 1988 13 p Presented at the 39th International Astronautical Federation Congress, Bangalore, India, 8-15 Oct. 1988 Previously announced in IAA as A89-17642

(REPT-882-440-116; IAF-88-037; ETN-89-94509) Avail: NTIS HC A03/MF A01

In the frame of a Hermes mission to service the Columbus module, an analysis of the role of pilots is presented. The discussion includes requirements, tasks to be performed onboard during rendezvous operations, the possibility of interaction by a pilot with

an automatic guidance navigation and control system, and the necessary non-machine interfaces. Proposals for specific man machine interface displays and their arrangement in the cockpit are presented. The conclusion is that the pilot must have continuous access to all necessary information and must have the possibility to intervene at each point in time. ESA

**N89-24357#** Centre National d'Etudes Spatiales, Toulouse (France).

# **HERMES-MTFF RENDEZVOUS STRATEGY AND COMPOSITE OPERATIONS**

L. MARECHAL, F. DIMAURO, D. HOGE, and W. FEHSE In ESA, International Symposium on Europe in Space: The Manned Space System p 185-190 Oct. 1988 Prepared in cooperation with ESA, Paris, France and ESA/ESTEC, Noordwijk, Netherlands Copyright Avail: NTIS HC A09/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

Hermes operations from injection into orbit to reentry are described. Parameters affecting the Hermes mission to the Columbus Man Tended Free Flyer (MTFF) are assessed. The role of the human operator in the rendezvous process is discussed. Orbital transfer and approach operations are outlined. It is concluded that the preferred approach to rendezvous and final approach should be along the V-bar. Composite configuration and composite attitude control satisfy internal servicing requirements with the present Hermes baseline. External servicing remains difficult and time consuming since the spaceplane is optimized for carrying a pressurized cargo only as requested by the servicing of the MTFF. ESA

**N89-26395#** Naval Ocean Systems Center, San Diego, CA.

# **TELETOUCH DISPLAY DEVELOPMENT, PHASE 1 Final Report, Oct. - Dec. 1987**

STEVEN F. WIKER Jul. 1988 66 p

(AD-A206919; NOSC/TR-1230) Avail: NTIS HC A04/MF A01 CSCL 12/9

Teleoperated manipulators currently in use rely mainly upon visual feedback to accomplish simple manipulation tasks. In some cases, to enhance manipulative capabilities, force reflection and positional correspondence are provided between slave manipulator and master controller arms, along with simple end-effector proximity and slip sensors. However, as noted by Bejczy, space-station assembly, satellite servicing in orbit, extraterrestrial exploration, and undersea operations (which require only seemingly ordinary manipulative capabilities) can overwhelm present teleoperated capabilities. To extend telemanipulative capabilities and applications, proposals have been made to improve the quality of current visual, proprioceptive, and kinesthetic feedback. Yet, without feeding back end-effector surface contact phenomena to the teleoperator, remote systems are difficult to field that possess a high degree of dextrous manipulative and haptic abilities. This report reviews human-tactile capabilities and previous efforts in tactile-display development, and recommends approaches for developing teletouch display systems for telerobotic systems. GRA

## 20

### **LIFE SCIENCES/HUMAN FACTORS/SAFETY**

Includes studies, models, planning, analyses and simulations for biological and medical laboratories, habitability issues for the performance and well-being of the crew, and crew rescue.

**A89-38270**

# **STUDY OF MAN-SYSTEM FOR JAPANESE EXPERIMENT MODULE (JEM) IN SPACE STATION**

HIDETAKA TANAKA, NORIFUMI IKEDA, KIMIKO HASEGAWA (Mitsubishi Heavy Industries, Ltd., Tobishima, Japan), and TAKAO YAMAGUCHI (National Space Development Agency of Japan,



Tokyo) In: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1789-1793. Copyright

Japanese Experiment Module (JEM) is one of the Space Station elements planned to be launched in 1997, and to be the first manned space system in Japan. The JEM will be attached to the NASA Space Station. In the JEM, various space environment utilization experiments will be carried out under the administration of the JEM management system. Included in the JEM man system is the hardware which supports crew safety, health, hygiene, nutrition, JEM operations, housekeeping and stowage. This paper clarifies the JEM man system concept and main man-machine interfaces such as the workstation, the workbench, etc. Author

AB9-38271

**JEM INTEGRATED CONTROL AND MANAGEMENT SYSTEM**  
MASAO HATADA, TETSUROU YOKOYAMA, TAKEYASU YOSHIOKA (National Space Development Agency of Japan, Tokyo), MASAO KUZUMAKI (Mitsubishi Heavy Industries, Ltd., Nagoya, Japan), HIDEO KOKUMI (Mitsubishi Heavy Industries, Ltd., Tobishima, Japan) et al. In: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1795-1800. Copyright

To assure adequate safety, reliability and maintainability of JEM (The Japanese Experiment Module), the concept of an 'Integrated Control and Management System' was studied. As the result of the study: (1) the control and management structure, (2) functional requirements, and (3) software methodologies were clarified. Author

AB9-38272

**SPACE STATION CREW TRAINING CONCEPT IN JAPAN**  
YASUSHI HORIKAWA, YASUHIKO FUJITA, KIYOTAKA YASHIRO (National Space Development Agency of Japan, Tokyo), and KAZUO INOUE (Kawasaki Heavy Industries, Ltd., Kobe, Japan) In: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1801-1805. Copyright

The Space Station (SS) will be operated and managed on-orbit by eight crew members. The on-orbit tour for crew members is planned to be six months. A Japanese crew member will also perform onboard activity as a member of international partner after the first JEM launch. Japan has already selected the flight crew members for the First Material Processing Test (FMPT), but it is necessary that the Station flight crew members should be selected and trained, considering various factors related to a longer mission than the FMPT mission. Furthermore, the recruitment, crew selection and training activities should be continuously maintained. Author

AB9-38273

**RELIABILITY OF MAN-MACHINE-ENVIRONMENT SYSTEM**  
JINBAO SUN and LIPING SHEN (Institute of Space Medico-Engineering, Beijing, People's Republic of China) In: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 1807-1811. Copyright

A man-machine-environment system engineering model is used to study the safety and reliability of manned space flight. Special attention is given to such aspects of human reliability as perception, information processing, procedure selection, operation execution, and physiological and psychological factors. Environmental aspects considered include ground and space factors, machine-induced factors such as shock and vibration, and factors influenced by man such as atmospheric composition, temperature, and humidity. R.R.

AB9-38589

**HUMAN TOLERANCE TO 100 PERCENT OXYGEN AT 9.5 PSIA DURING FIVE DAILY SIMULATED 8-HOUR EVA EXPOSURES**  
JAMES T. WEBB, ROBERT M. OLSON, ROBERT W. KRUTZ, JR., GENE DIXON, and PAUL T. BARNICOTT (Krug International Corp., San Antonio; USAF, School of Aerospace Medicine, Brooks AFB, TX) Aviation, Space, and Environmental Medicine (ISSN 0095-6562), vol. 60, May 1989, p. 415-421. refs (Contract F33615-85-C-4503) (AD-A211431) Copyright

Twenty-one subjects were exposed to 100 percent oxygen at 9.5 psia for 5 consecutive days, 8 h/d while performing moderate exercise to simulate a typical work-week in the proposed pressure suit environment. No decompression sickness or venous gas bubbles were detected. Pulmonary function tests, physical exams, blood analyses, arterial oxygen saturation monitoring, and X-rays showed no evidence of oxygen toxicity under these conditions. These results suggest that a 100 percent oxygen, 9.5 psia pressure suit environment could avoid both decompression sickness and oxygen toxicity during EVAs of comparable duration and physical activity. Author

AB9-38744

**HUMAN DIMENSIONS IN SPACE DEVELOPMENT**  
PHILIP R. HARRIS (California, University; Harris International, La Jolla) Space Policy (ISSN 0265-9646), vol. 5, Mar 1989, p. 147-154. refs Copyright

Biological and behavioral science issues related to space exploration and colonization are examined. Problems associated with living in a space environment for long periods of time are discussed, including group behavior and dynamics in space flight, the environment created at space stations, management on earth and in orbit, selection and training of space station inhabitants, and planning, establishing, and governing space settlements. Various aspects of human factors in space development are addressed, such as physical, sociological, financial, legal, managerial, psychological, cultural, political, education, and communication factors. R.B.

AB9-42153\* National Aeronautics and Space Administration, Ames Research Center, Moffett Field, CA.

**THE EFFECTS OF WINDOW SHAPE AND RETICLE PRESENCE ON PERFORMANCE IN A VERTICAL ALIGNMENT TASK**  
ERIKA L. ROSENBERG, RICHARD F. HAINES, and KEVIN JORDAN (NASA, Ames Research Center, Moffett Field; San Jose State University, CA) Aviation, Space, and Environmental Medicine (ISSN 0095-6562), vol. 60, June 1989, p. 543-548. refs (Contract NCC2-327) Copyright

This study was conducted to evaluate the effect of selected interior work-station orientational cuing upon the ability to align a target image with local vertical in the frontal plane. Angular error from gravitational vertical in an alignment task was measured for 20 observers viewing through two window shapes (square, round), two initial orientations of a computer-generated space shuttle image, and the presence or absence of a stabilized optical alignment reticle. In terms of overall accuracy, it was found that observer error was significantly smaller for the square window and reticle-present conditions than for the round window and reticle-absent conditions. Response bias data reflected an overall tendency to undershoot and greater variability of response in the round window/no reticle condition. These results suggest that environmental cuing information, such as that provided by square window frames and alignment reticles, may aid in subjective orientation and increase accuracy of response in a Space Station proximity operations alignment task. Author

AB9-42163

**INTERPERSONAL AND GROUP-BEHAVIOR SKILLS TRAINING FOR CREWS ON SPACE STATION**  
JOHN M. NICHOLAS (Loyola University, Chicago, IL) Aviation, Space, and Environmental Medicine (ISSN 0095-6562), vol. 60,

June 1989, p. 603-608. Research supported by Loyola University. refs

Copyright

With the advent of Space Station, planners must come to terms with the inevitable psychosocial crew problems that accompany long-term confinement. Although some problems may be resolvable with the assistance of an on-board professional therapist-consultant, others can only be settled by whole-crew training in interpersonal, emotional-support, and group-interaction skills. This article describes problem situations, kinds of skills training needed to resolve them, and the resistance that proposals for behavioral training might encounter. Author

**A89-43715\*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

#### PHYSIOLOGICAL EFFECTS OF SPACE FLIGHT

CAROLYN L. HUNTOON (NASA, Johnson Space Center, Houston, TX) IN: Space - A new community of opportunity; Proceedings of the Thirty-fourth Annual AAS International Conference, Houston, TX, Nov. 3-5, 1987. San Diego, CA, Univelt, Inc., 1988, p. 219-224.

(AAS PAPER 87-644) Copyright

Data from Skylab and Space Shuttle missions are used as a framework for discussing the physiological effects of space flight. Consideration is given to motion sickness, and changes in body fluids, the cardiovascular system, and red blood cell counts. In addition, changes in muscle mass, bone mass, and the immune system, and neurosensory disturbances are examined. R.B.

**A89-43711\*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

#### MEDICAL CARE DELIVERY IN SPACE

DON F. STEWART (NASA, Johnson Space Center, Houston, TX) IN: Space - A new community of opportunity; Proceedings of the Thirty-fourth Annual AAS International Conference, Houston, TX, Nov. 3-5, 1987. San Diego, CA, Univelt, Inc., 1988, p. 225-230.

(AAS PAPER 87-645) Copyright

Consideration is given to the delivery of medical care in space. The history of aviation medicine is reviewed. Medical support for the early space programs is discussed, including the Mercury, Gemini, Apollo, and Skylab programs. The process of training crew members for basic medical procedures for the Space Shuttle program is briefly described and medical problems during the Shuttle program are noted. Plans for inflight medical care on the Space Station are examined, including the equipment planned for the Health Maintenance Facility, the use of exercise to help prevent medical problems. R.B.

#### **A89-45792** PRELIMINARY ANALYSIS OF FIRE SUPPRESSION METHODS FOR THE SPACE STATION

STUART KRAMER and JOSEPH SHERIDAN (USAF, Institute of Technology, Wright-Patterson AFB, OH) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 809-819. refs

Copyright

The choice of a fire suppression system for the Space Station remains open. Several alternatives have been suggested, each with particular advantages and disadvantages. The problem is complicated by the relative lack of knowledge about the behavior of fire and extinguishing agents in microgravity. The purpose of this paper is to suggest a fire suppression system for the Station given present knowledge. Portable carbon dioxide extinguishers for small fires, and a fixed Halon 1201 system for large-scale fires or for explosion suppression are recommended. Author

#### **A89-45794** EVALUATION OF METHODS FOR RECOVERING CREW MEMBERS AND EQUIPMENT ADRIFT FROM THE SPACE STATION

THOMAS SELINKA (USAF, Space Command, Peterson AFB, CO) and STUART KRAMER (USAF, Institute of Technology,

Wright-Patterson AFB, OH) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 832-843. refs

Copyright

A systematic process for evaluating the alternatives for recovering adrift crew members and equipment from the Space Station is developed and used to perform a preliminary analysis of the proposed Space Station systems. The alternatives are grouped into seven classes: self rescue, station supported rescue, an unmanned free-flying unit, a manned free-flying unit, the Crew Emergency Return Vehicle, the Space Shuttle, and systems based on the Orbital Maneuvering Vehicle. The performance of each alternative is evaluated for a set of representative scenarios. R.B.

#### **A89-45826** SURGERY IN THE MICROGRAVITY ENVIRONMENT

PAUL CHASTAIN, MEL DEALIE, and TODD DIERLAM IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 1206-1219. refs

Copyright

As man becomes more active in space, the possibility of major medical emergencies requiring surgical procedures will increase. Surgery in the microgravity environment involves many challenges not found on earth. Problems such as the flow of intravenous fluids, the operation of suction devices, and the containment of body fluids are key areas of concern. The solutions to these problems require new equipment and expertise. This paper examines these problems and proposes some possible solutions. Author

**A89-46800\*** Pioneer Aerospace Corp., Melbourne, FL.

#### ADVANCED SPACE RECOVERY SYSTEMS

WILLIAM K. WALES (Pioneer Aerospace Corp., Melbourne, FL) AIAA, ASME, SAE, and ASCE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 14 p.

(Contract NAS8-26631)

(AIAA PAPER 89-2399) Copyright

The design evolution of a space recovery system designed by a NASA-contracted study is described, with particular attention given to the design of a recovery system for a propulsion/avionics module (P/AM), which weighs 60,000 lb at the recovery initiation and achieves subsonic terminal descent at or above 50,000 ft msl. The components of the recovery system concept are described together with the operational sequences of the recovery. The recovery system concept offers low cost, low weight, good performance, a potential for pinpoint landing, and an operational flexibility. I.S.

**A89-48173\*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

#### HUMAN TOLERANCE TO SPACE FLIGHT

C. L. HUNTOON (NASA, Johnson Space Center, Houston, TX) AIAA and NASA, Symposium on the Maintainability of Aerospace Systems, Anaheim, CA, July 26, 27, 1989. 9 p. refs

(AIAA PAPER 89-5062) Copyright

Medical studies of astronauts and cosmonauts before, during, and after space missions have identified several effects of weightlessness and other factors that influence the ability of humans to tolerate space flight. Weightlessness effects include space motion sickness, cardiovascular abnormalities, reduction in immune system function, loss of red blood cells, loss of bone mass, and muscle atrophy. Extravehicular activity (EVA) increases the likelihood that decompression sickness may occur. Radiation also gives reason for concern about health of crewmembers, and psychological factors are important on long-term flights. Countermeasures that have been used include sensory preadaptation, prebreathing and use of various air mixtures for EVA, loading with water and electrolytes, exercise, use of pharmacological agents and special diets, and psychological

support. It appears that humans can tolerate and recover satisfactorily from at least one year of space flight, but a number of conditions must be further ameliorated before long-duration missions can be considered routine. *Author*

A89-50738

**PHYSIOLOGICAL PROBLEMS FOR MAN IN SPACE**

T. SCRATCHERD and D. GRUNDY (Sheffield, University, England) *British Interplanetary Society, Journal* (ISSN 0007-084X), vol. 42, Aug. 1989, p. 357-359.

Copyright

Several physiological problems associated with space flight are reviewed. Consideration is given to the characteristics of the space vehicle environment, the physiological response to space flight, and the effects of microgravity on the muscles. Also, the effects on red blood cells and hemoglobin, the process of readapting to earth conditions, and the psychological effects of a stressful environment are discussed. *R.B.*

A89-50743

**FOOD FOR THOUGHT - NUTRITIONAL PROBLEMS IN SPACE**

D. GRUNDY and T. SCRATCHERD (Sheffield, University, England) *British Interplanetary Society, Journal* (ISSN 0007-084X), vol. 42, Aug. 1989, p. 374-377. refs

Copyright

The nutritional requirements during spaceflight are examined, emphasizing the ways in which microgravity may alter these requirements. The protein, fat, and carbohydrate requirements during spaceflight are considered. The primary functions of vitamins and minerals are reviewed. The daily dietary requirements of a 70-kg man in space are estimated. The nutritional issues related to long-duration space missions are discussed. *R.B.*

A89-54201

**LIFE SCIENCES AND SPACE RESEARCH XXIII(4) - RADIATION BIOLOGY; PROCEEDINGS OF THE TOPICAL MEETINGS AND WORKSHOP XIX OF THE 27TH COSPAR PLENARY MEETING, ESPOO, FINLAND, JULY 18-25, 1988**

U. HAGEN, ED. (Gesellschaft fuer Strahlenforschung mbH, Institut fuer Strahlenbiologie, Neuherberg, Federal Republic of Germany), G. HORNECK, ED. (DLR, Institut fuer Flugmedizin, Cologne, Federal Republic of Germany), and R. J. M. FRY, ED. (Oak Ridge National Laboratory, TN) *Meetings and Workshop sponsored by COSPAR. Advances in Space Research* (ISSN 0273-1177), vol. 9, no. 10, 1989, 344 p. For individual items see A89-54202 to A89-54239.

Copyright

Topics discussed in this volume are on the molecular and cellular effects of heavy ions, the impact of environmental factors on radiobiological processes in space, and radiation research related to Space Station and missions beyond the magnetosphere. Papers are presented on physical events in the track structure of heavy ions and their relation to alterations of biomolecules, the stochastic effects of HZE-induced microlesions, DNA lesion and cell death by alpha-particles and nitrogen ions, molecular mechanisms responsible for neoplastic cell transformation by high-LET radiation, and the combined effects of radiation and trauma. Attention is also given to photoproducts in DNA irradiated in vitro and in vivo under extreme environmental conditions, a parametric study of space radiation exposures to critical body organs for low-earth-orbit missions, a model analysis of Space Shuttle dosimetry data, and late cataractogenesis caused by particulate radiations and photons in long-lived mammalian species. *I.S.*

A89-54202

**RADIATION BIOLOGY IN SPACE - A CRITICAL REVIEW**

U. HAGEN (Gesellschaft fuer Strahlenforschung mbH, Institut fuer Strahlenbiologie, Neuherberg, Federal Republic of Germany) (COSPAR, Plenary Meeting, 27th, Topical Meetings and Workshop XIX on Life Sciences and Space Research XXIII(4) - Radiation Biology, Espoo, Finland, July 18-25, 1988) *Advances in Space Research* (ISSN 0273-1177), vol. 9, no. 10, 1989, p. 3-8. refs

Copyright

A short summary of the results of radiobiological studies in space or on respective particles on ground is given. Among the various types of radiation in space, the effect of heavy ions with high energy are most essential. Cell death, mutation and malignant transformation can be studied on ground with heavy ions of different energy with suitable accelerators or in space. In space, however, the effect of microgravity has to be considered and there are hints that under weightlessness the biological effect of radiation may be enhanced. *Author*

N89-23904# National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, AL.

**ASTRONAUT TOOL DEVELOPMENT: AN ORBITAL REPLACEABLE UNIT-PORTABLE HANDHOLD**

JOHN W. REDMON, JR. In *its* The 23rd Aerospace Mechanisms Symposium p 181-193 Mar. 1989

Avail: NTIS HC A15/MF A02 CSCL 05/8

A tool to be used during astronaut Extra-Vehicular Activity (EVA) replacement of spent or defective electrical/electronic component boxes is described. The generation of requirements and design philosophies are detailed, as well as specifics relating to mechanical development, interface verifications, testing, and astronaut feedback. Findings are presented in the form of: (1) a design which is universally applicable to spacecraft component replacement, and (2) guidelines that the designer of orbital replacement units might incorporate to enhance spacecraft on-orbit maintainability and EVA mission safety. *Author*

N89-24364# European Space Agency, European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Product Assurance and Safety Dept.

**ESA SAFETY REQUIREMENTS**

L. TEDEMAN In *its* International Symposium on Europe in Space: The Manned Space System p 247-251 Oct. 1988

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The ESA safety policy, designed to protect human life, investments, and the environment is outlined. A risk assessment procedure which recognizes the lack of objective statistical data is discussed. It considers the consequences, frequency, and probability of an undesirable hazardous event. This risk assessment is applied as an iterative process during all project phases. *ESA*

N89-24371# European Space Agency, European Space Operations Center, Darmstadt (Germany, F.R.).

**THE IMPACT OF MANNED SPACE FLIGHT OPERATIONS ON THE SAFETY AND RELIABILITY ASPECTS OF GROUND SYSTEMS REQUIREMENTS**

DAVID E. B. WILKINS In *its* International Symposium on Europe in Space: The Manned Space System p 337-347 Oct. 1988

Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

Reliability and safety standards for the ESA in-orbit infrastructure ground segment are discussed. The ground segment design process is outlined. Hardware and software availability are mentioned. Human factors in operational reliability are reviewed. *ESA*

N89-24374# European Space Agency, Paris (France).

**THE TRAINING CONCEPT FOR ESA ASTRONAUTS AND THE ASSOCIATED FACILITIES**

H. D. HOPKINS In *its* International Symposium on Europe in Space: The Manned Space System p 367-369 Oct. 1988

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The number of astronauts required for the Hermes program is estimated at 12. Training facilities needed are determined for basic training and specialized and mission training. *ESA*

N89-24396# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.).

**CREW TRAINING ASPECTS**

F. J. DEMOND, W. MUELLER-BREITKREUTZ, and H. G.



NEUHAUSER In ESA, International Symposium on Europe in Space: The Manned Space System p 541-549 Oct. 1988  
Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

Astronaut training for Hermes and Columbus is discussed. Experience from the German Spacelab missions is reviewed and training facilities needed for Hermes and Columbus are indicated. Two main types of facilities are proposed: an integrated system training facility with full scale mock-ups of the specific space elements; and single system training facilities, which allow training on single subsystems or payload elements. ESA

**N89-24413\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

#### **FIRE SAFETY APPLICATIONS FOR SPACECRAFT**

ROBERT FRIEDMAN and SANDRA L. OLSON 1989 29 p  
Presented at the Symposium on Aircraft Fire Safety, Sintra, Portugal, 22-26 May 1989; sponsored by the AGARD/NATO Propulsion Energetics Panel  
(NASA-TM-101463; E-4511; NAS 1.15:101463) Avail: NTIS HC A03/MF A01 CSCL 22/2

Fire safety for spacecraft is reviewed by first describing current practices, many of which are adapted directly from aircraft. Then, current analyses and experimental knowledge in low-gravity combustion, with implications for fire safety are discussed. In orbiting spacecraft, the detection and suppression of flames are strongly affected by the large reduction in buoyant flows under low gravity. Generally, combustion intensity is reduced in low gravity. There are some notable exceptions, however, one example being the strong enhancement of flames by low-velocity ventilation flows in space. Finally, the future requirements in fire safety, particularly the needs of long-duration space stations in fire prevention, detection, extinguishment, and atmospheric control are examined. The goal of spacecraft fire-safety investigations is the establishment of trade-offs that promote maximum safety without hampering the useful human and scientific activities in space.

Author

**N89-24792\*** National Academy of Sciences - National Research Council, Washington, DC. Committee on Human Factors.

#### **HUMAN FACTORS IN AUTOMATED AND ROBOTIC SPACE SYSTEMS: PROCEEDINGS OF A SYMPOSIUM. PART 1**

THOMAS B. SHERIDAN, ed., DANA S. KRUSER, ed., and STANLEY DEUTSCH, ed. 1987 475 p Symposium held in Washington, DC, 29-30 Jan. 1987  
(Contract NASW-4071)  
(NASA-CR-182495; NAS 1.26:182495) Avail: NTIS HC A20/MF A03 CSCL 05/8

Human factors research likely to produce results applicable to the development of a NASA space station is discussed. The particular sessions covered in Part 1 include: (1) system productivity - people and machines; (2) expert systems and their use; (3) language and displays for human-computer communication; and (4) computer aided monitoring and decision making. Papers from each subject area are reproduced and the discussions from each area are summarized. A.D.

**N89-24793\*** McDonnell-Douglas Astronautics Co., Huntsville, AL.

#### **THE HUMAN ROLE IN SPACE (THURIS) APPLICATIONS STUDY. FINAL BRIEFING**

GEORGE W. MAYBEE Oct. 1987 73 p  
(Contract NAS6-36638)  
(NASA-CR-183590; NAS 1.26:183590; MDC-W5125-2) Avail: NTIS HC A04/MF A01 CSCL 05/8

The THURIS (The Human Role in Space) application is an iterative process involving successive assessments of man/machine mixes in terms of performance, cost and technology to arrive at an optimum man/machine mode for the mission application. The process begins with user inputs which define the mission in terms of an event sequence and performance time requirements. The desired initial operational capability date is also an input requirement. THURIS terms and definitions (e.g., generic

activities) are applied to the input data converting it into a form which can be analyzed using the THURIS cost model outputs. The cost model produces tabular and graphical outputs for determining the relative cost-effectiveness of a given man/machine mode and generic activity. A technology database is provided to enable assessment of support equipment availability for selected man/machine modes. If technology gaps exist for an application, the database contains information supportive of further investigation into the relevant technologies. The present study concentrated on testing and enhancing the THURIS cost model and subordinate data files and developing a technology database which interfaces directly with the user via technology readiness displays. This effort has resulted in a more powerful, easy-to-use applications system for optimization of man/machine roles. Volume 1 is an executive summary. A.D.

**N89-24794\*** National Academy of Sciences - National Research Council, Washington, DC. Committee on Human Factors.

#### **HUMAN FACTORS IN AUTOMATED AND ROBOTIC SPACE SYSTEMS: PROCEEDINGS OF A SYMPOSIUM. PART 2**

14 Aug. 1987 446 p Symposium held in Washington, DC, 29-30 Jan. 1987  
(Contract NASW-4071)  
(NASA-CR-182496; NAS 1.26:182496) Avail: NTIS HC A19/MF A03 CSCL 05/8

Human factors research likely to produce results applicable to the development of a NASA space station is discussed. The particular sessions covered in Part 2 include: (1) computer aided monitoring and decision making; (2) telepresence and supervisory control; (3) social factors in productivity and performance; and (4) the human role in space systems. Papers from each subject area are reproduced and the discussions from each area are summarized. A.D.

**N89-28243\*** Dornier System G.m.b.H., Friedrichshafen (Germany, F.R.).

#### **THE EUROPEAN SPACE SUIT SYSTEM**

N. HERBER In ESA, Third European Symposium on Space Thermal Control and Life Support Systems p 211-219 Dec. 1988  
Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

The European Space Suit System (ESSS) status is foreseen for servicing of various elements of space infrastructure within typical operational scenarios based on Hermes. As a result of different EVA studies the ESSS concept was defined and structured in three modules: the EVA Suit Enclosure Module, the EVA Life Support Module, and the EVA Information and Communication Module. The fourth equipment which has to be seen as a part of the Space Suit System as well, is the EVA Support and Verification Equipment responsible for suit accommodation, recharging, check out and the like. ESA

**N89-28246\*** European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).

#### **EVA AND HUMAN PHYSIOLOGY**

B. SVENSSON, L. VOGT, and N. HERBER (Dornier System G.m.b.H., Friedrichshafen, Germany, F.R.) In its Third European Symposium on Space Thermal Control and Life Support Systems p 233-238 Dec. 1988  
Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars

The crew requirements for the European EVA space suit are divided into human safety, human physiology, and crew performance and productivity requirements. The human physiology requirements addresses areas like anthropometry, biomechanics, psychosensory performance and protection, atmosphere composition and pressure, metabolism, weightlessness effects and radiation. It is planned to perform validation of critical parameters by tests, e.g., the establishment of risk factors for decompression

sickness. Considerations and test results of physiological parameters will be given to the ESA medical board, which will give recommendations on acceptable risk factors, maximum and minimum exposure levels, and comfort levels for the EVA crew members. ESA

**N89-28262\*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

#### TEST RESULTS ON RE-USE OF RECLAIMED SHOWER WATER: SUMMARY

C. E. VEROSTKO, R. GARCIA, R. SAUER, A. T. LINTON, T. ELMS, and R. P. REYSA (Boeing Aerospace Co., Houston, TX.) In *ESA, Third European Symposium on Space Thermal Control and Life Support Systems* p 353-360 Dec. 1988. Copyright Avail: NTIS HC A99/MF A04; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders or 45 US dollars CSCL 05/8

A microgravity whole body shower (WBS) and waste water recovery systems (WWRS) were evaluated in three separate closed loop tests. Following a protocol similar to that anticipated for the U.S. Space Station, test subjects showered in a prototype whole body shower. The WWRS processes evaluated during the test series were phase change and reverse osmosis (RO). A preprototype Thermoelectric Integrated Hollow Fiber Membrane Evaporation Subsystem phase change process was used for the initial test with chemical pretreatment of the shower water waste input. The second and third tests concentrated on RO technologies. The second test evaluated a dynamic RO membrane consisting of zirconium oxide polyacrylic acid (ZOPA) membranes deposited on the interior diameter of 316L porous stainless steel tubes while the final test employed a thin semipermeable RO membrane deposited on the interior surface of polysulfone hollow fibers. All reclaimed water was post-treated for purity using ion exchange and granular activated carbon beds immediately followed by microbial control treatment using both heat and iodine. The test hardware, controls exercised for whole body showering, types of soaps evaluated, shower subject response to reclaimed water showering, and shower water collection and chemical pretreatment (if required) for microbial control are described. The WWRS recovered water performance and the effectiveness of the reclaimed water post-treatment techniques used for maintaining water purity and microorganism control are compared. Results on chemical and microbial impurity content of the water samples obtained from various locations in the shower water reuse system are summarized. ESA

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### GENERAL

Includes descriptions, analyses, trade studies, commercial opportunities, published proceedings, seminars, hearings, historical summaries, policy speeches and statements that have not previously been included.

**N89-33029**

#### ENVIRONMENTAL IMPACT OF SPACE ACTIVITIES AND MEASURES FOR INTERNATIONAL PROTECTION

QIZHI HE *Journal of Space Law* (ISSN 1012-3431), vol. 16, no. 2, 1988, p. 117-127. refs. Copyright

The response of international space law to the impact of space activities on the environment is discussed. Chemical, biological, and radiological pollution arising from space activities is described. Provisions of existing treaties to protect the space environment are examined, including the 1963 Partial Test Ban Treaty, the 1967 Outer Space Treaty, the 1979 Moon Agreement, and the 1976 Convention on the Prohibition of Military and Other Hostile Use of Environmental Modification Techniques. Recommendations to strengthen international protection measures are given, including

the definition of terminology, a ban on intentional destruction and fragmentation on space objects, measures to minimize the production of debris, the establishment of an international expert group and a mandatory consultation regime, furthering the norms of liability, and increasing international cooperation. R.B.

**N89-33120**

#### MAJOR SPACE EFFORT MOBILIZED TO BLUNT ENVIRONMENTAL THREAT

CRAIG COVAULT *Aviation Week and Space Technology* (ISSN 0005-2175), vol. 130, March 13, 1989, p. 36, 37, 43, 44. Copyright

NASA's Mission to Planet Earth, a proposed project which would track global environmental change and document the complex interactions among the land, sea, and air, is described. Mission to earth's primary objective is to gather information that would influence U.S. and international policy decisions on the environment. The role of Europe and Japan in this project is discussed. K.K.

**N89-33447**

#### TRIBOLOGY PROBLEMS IN FUTURE SPACECRAFT

KEITH F. DUFRANE and JERROLD W. KANNEL (Battelle Columbus Laboratories, OH) In: *Engineered materials for advanced friction and wear applications; Proceedings of the International Conference, Gaithersburg, MD, Mar. 1-3, 1988. Metals Park, OH, ASM International, 1988, p. 181-186. refs. Copyright*

Techniques for increasing the service life of precision bearings for space applications are described and illustrated with drawings, diagrams, and micrographs. The increased service-life, power-density, service-factor, and size requirements of planned space missions are discussed; ongoing efforts to produce higher-performance lubricants are reviewed; and particular attention is given to (1) the use of electronic sensors and feedback circuits to control bearing position on a laboratory precision spindle mechanism and (2) a bronze-filled polytetrafluoroethylene bearing separator providing transfer-film lubrication for the high-pressure oxidizer pumps of rocket engines. T.K.

**N89-33921\*** National Aeronautics and Space Administration, Washington, DC.

#### INFRASTRUCTURE CONSIDERATIONS

URIEL LOVELACE (NASA, Office of Exploration, Washington, DC), PHIL SUMRALL (NASA, Marshall Space Flight Center, Huntsville, AL), and BRIAN PRITCHARD (NASA, Langley Research Center, Hampton, VA) *Aerospace America* (ISSN 0740-722X), vol. 27, April 1989, p. 38-40. Copyright

An evaluation is made of performance requirements and technology development prospects for the logistical capacity entailed by manned space exploration. While the Space Shuttle will suffice for the launch of crews to a LEO Space Station, in support of such exploration missions, cargo transport will require 500-1000 tonne annual payload capacity launchers. As a first step toward satisfaction of such requirements, NASA has undertaken the development of the Shuttle-C unmanned Space Shuttle derivative. This will be followed by the Shuttle-Z derivative-family, aimed at meeting the needs of Mars missions. Joint USAF/NASA Advanced Launch System development will allow a given launch to place 91 tonnes in LEO. O.C.

**N89-34354**

#### A CIVIL ENGINEER'S VIEW FROM SPACE

JAMES D. A. VAN HOFEN (Bechtel National, Inc., San Francisco, CA) *Journal of Aerospace Engineering* (ISSN 0893-1321), vol. 1, Jan. 1989, p. 28-34. Copyright

An evaluation is made of prospective developments in the orbital systems fields to which civil engineers may be able to fruitfully contribute. Identified areas of civil engineering interest encompass real-time remote sensing for surveying, the structural engineering design of large space platforms, extraterrestrial manned

environment engineering, hydraulic engineering in zero-g environments, and robotics. "Space engineering" is seen as an organic extension of civil engineering whose clear-sighted and timely anticipation should soon lead to the appropriate modification and expansion of university civil engineering curricula. O.C.

#### AB9-34360

##### PREPARING TO BRIDGE THE LUNAR GAP

STEPHEN J. SIMMERER (U.S. Army, Directorate of Evaluation and Standardization, Fort Belvoir, VA) *Journal of Aerospace Engineering* (ISSN 0893-1321), vol. 1, April 1988, p. 117-128. refs

Copyright

The U.S. is committed to the exploration of and the expansion into space. A manned earth-orbiting Space Station is planned for the next decade and studies continue looking at manned lunar bases. Appropriate planning should be initiated for such a mission now as a high national priority. Many systems must be examined and technologies developed as soon as possible. Some of these include types of power sources, life support systems, construction equipment and techniques, construction methods, lunar mapping, and logistical constraints. Author

#### AB9-34366

##### ENGINEERING TEST SUPPORT FOR CONSTRUCTION IN SPACE

STEWART W. JOHNSON (BDM Corp., Albuquerque, NM) and RAYMOND S. LEONARD (Ad Astra, Ltd., Santa Fe, NM) *Journal of Aerospace Engineering* (ISSN 0893-1321), vol. 1, Oct. 1988, p. 206-218. Research supported by BDM Corp. and Ad Astra, Ltd. refs

Copyright

Reasons are presented for the importance of engineering testing approach-expertise involvement in the analysis, design, and development of capabilities for the establishment of a manned base on the moon and human flight to Mars, especially in the cases of construction requirements for which the use of extraterrestrial resources is envisaged. The effectiveness and suitability of mission equipment and proposed resource-extraction processes must also be demonstrated through analysis, simulation, ground testing, and flight testing; in particular, the facilities for testing and evaluation of extraterrestrial facilities must be acquired with ample time. O.C.

#### AB9-34367

##### COMMON CHARACTERISTICS OF TERRESTRIAL AND SPACE CONSTRUCTION

LEONHARD BERNOLD (Maryland, University, College Park) *Journal of Aerospace Engineering* (ISSN 0893-1321), vol. 1, Oct. 1988, p. 219-237. Research supported by the Minta Martin Research Fund. refs

Copyright

The novel and difficult problems that may be anticipated to arise in the construction of the first stationary facilities in space and on the lunar surface can be addressed through the study of cases in which terrestrial construction efforts have had to deal with extreme conditions: these cases are represented by sea-floor construction and the building of large structures on the frozen terrain of the Arctic and Antarctic regions. The body of logistical experience and design practices that have emerged from such efforts are presently projected onto the anticipated extraterrestrial construction tasks, with emphasis on the application of prefabricated methods, the use of automation and robotics, the configuration and deployment of excavation and terrain-shaping equipment, materials management, and the simulation of construction processes. O.C.

#### AB9-34370

##### STRUCTURAL ENGINEER'S CONCEPT OF LUNAR STRUCTURES

PHILIP Y. CHOW and T. Y. LIN (T. Y. Lin International, San Francisco, CA) *Journal of Aerospace Engineering* (ISSN

0893-1321), vol. 2, Jan. 1989, p. 1-9.

Copyright

An ideal structural basis for a lunar base would be extremely light in weight to facilitate transportation from earth, and extremely compact in order to minimize cargo volume enroute; it must also be easily deployable with minimum manpower and equipment. Attention is presently given to a self-supporting composite membrane structure concept, in which a double-skin fabric membrane derives stiffness and sufficient strength to withstand the 14 psi of internal pressurization required for human habitation from a structural foam, such as polyurethane, of 0.32-0.64 gm/sq cm density. The configuration of the structure thus formed is that of a saucer-shaped dome with a toroidal rim. O.C.

#### AB9-34387

##### SPACE SETTLEMENTS - SOONER THAN WE THINK?

THOMAS F. ROGERS *Ad Astra* (ISSN 1041-102X), vol. 1, Jan. 1989, p. 30-34.

Copyright

The possibility of establishing a relatively large private space settlement in space is discussed. The plans for the Space Station are reviewed. The economic, technological, and safety considerations related to the construction of a space settlement are examined. The possible characteristics of such a settlement are outlined. R.B.

#### AB9-34388

##### GETTING A GRIP ON SPACE

RAY SPANGENBURG and DIANE MOSER *Ad Astra* (ISSN 1041-102X), vol. 1, March 1989, p. 31-34.

Copyright

The development of gloves for EVA on the Space Station is discussed. The gloves used in the various space missions are described, noting the problems associated with their designs. The problems of flexibility, tactility, fabric selection, and the effects of pressure are considered. R.B.

AB9-35802\*# National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, TX.

##### GEOLOGICAL APPLICATIONS OF THE SPACE STATION

##### CORE PLATFORM

DAVID L. AMSBURY (NASA, Johnson Space Center, Houston, TX) IN: Thematic Conference on Remote Sensing for Exploration Geology, 6th, Houston, TX, May 16-19, 1988, Proceedings, Volume 2. Ann Arbor, MI, Environmental Research Institute of Michigan, 1988, p. 671-676.

The manned core platform of the Space Station will repeatedly provide observations of the tropical and subtropical parts of earth from about 500 km altitude in a 28.5 degree orbit. This orbit covers most of the landmasses in the Southern Hemisphere, half of the world ocean, and more than 120 nations. The platform can provide remote-sensing activities by means of: (1) sensors attached to structural members of the platform; (2) sensors deployed on one or more pointable platforms attached to structural members, or man-tended in separate orbits; (3) sensors operated from the resource nodes; (4) sensors operated through earth-viewing, optical-quality windows; and (5) hand-held cameras operated by crew members throughout the facility. Major applications of observations from the core platform in the exploration for and production of resources are discussed. Author

AB9-36959\* National Aeronautics and Space Administration, Washington, DC.

##### PLANNING FOR THE SCIENTIFIC USE OF THE INTERNATIONAL SPACE STATION COMPLEX

R. E. HALPERN (NASA, Office of Space Station, Washington, DC) (COSPAR, ESA, and International Union of Crystallography, Plenary Meeting, 27th, Symposium on Microgravity, 16th, Espoo, Finland, July 18-29, 1988) *Advances in Space Research* (ISSN 0273-1177), vol. 8, no. 12, 1988, p. 89-95.

Copyright

Plans for the development of an international Space Station complex in cooperation with Japan, Canada, and the European



## 21 GENERAL

Space Agency are reviewed. The discussion covers the planned uses of the Space Station, the principal research facilities, allocation of the resources available to the research facilities, and tactical and strategic planning related to the Space Station project. Particular attention is given to problems related to microgravity sciences and approaches to the solutions of these problems.

V.L.

### A89-38392

#### THE CANADIAN SPACE PROGRAM

W. M. EVANS (Ministry of State for Science and Technology, Ottawa, Canada) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 2633-2638.

Copyright

An overview of the Canadian space program is given, with an emphasis on the Long-Term Space Plan adopted in 1986. Topics addressed include the previous history of space activities in Canada, the Canadian contribution to the International Space Station (costs, benefits, and proposed uses), space-science programs, Canadian astronauts, the Msat communication and Radarsat remote-sensing satellites, and the proposed annual funding levels (increasing by about 10 percent/yr to 300 million Canadian dollars in 1992).

T.K.

A89-38394\* National Aeronautics and Space Administration, Washington, DC.

#### THE CURRENT STATUS OF AND FUTURE OUTLOOK FOR THE NASA SPACE PROGRAM

D. D. MYERS (NASA, Washington, DC) IN: International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Proceedings. Volume 2. Tokyo, AGNE Publishing, Inc., 1988, p. 2643-2646.

Copyright

A brief general overview of NASA programs and planning is presented. Topics discussed include long-term policy goals (creating commercial opportunities, construction of the International Space Station, and manned planetary missions), the scientific and technological projects planned for the Space Station, the key role of the Space Station in solar-system exploration, the pathfinder-technologies concept, and the comprehensive remote-sensing program Mission to Planet Earth.

T.K.

### A89-38579

#### RACE INTO SPACE - THE SOVIET SPACE PROGRAMME

BRIAN HARVEY (Chichester, England/New York, Ellis Horwood, Ltd./Halsted Press, 1988, 381 p. refs

Copyright

The importance of the Soviet space programme to the USSR's economic development is discussed. Particular attention is given to the building of the Mir station in the 1980s, the construction of a new generation of sophisticated booster rockets, and projected flights to the asteroids and Mars. It is believed that, while the race into space may now be over, the conquest of the solar system may be about to begin.

K.K.

### A89-39225

#### LEGAL ASPECTS OF THE INTERNATIONAL SPACE STATION AGREEMENT (RECHTLICHE ASPEKTE DES UEBEREINKOMMENS UEBER DIE INTERNATIONALE RAUMSTATION)

JUERGEN REIFARTH (Zeitschrift fuer Luft- und Weltraumrecht (ISSN 0340-8329), vol. 38, March 1989, p. 35-52. In German.

Copyright

The performance of the International Space Station agreement is discussed. The division of rights and duties among the partners to the agreement is addressed, and cooperative efforts envisioned in the agreement are taken into consideration. The impact of outer space law on the agreement is examined.

C.D.

### A89-39740

#### IS 'THE RIGHT STUFF' THE RIGHT STUFF?

JERROLD M. POST (George Washington University, Washington, DC) Space Policy (ISSN 0265-9646), vol. 5, May 1989, p. 99-102. refs

Copyright

Consideration is given to the qualities and personality characteristics required of astronauts on a long-duration Space Station mission. The importance of interpersonal issue for an international crew on a permanently manned spacecraft is discussed. The qualities ascribed to previous astronauts are outlined and the differences between previous mission and a Space Station mission are noted. It is concluded that the qualities of previous astronauts are necessary for a long-term mission and that additional interpersonal skills may be required for working for long periods of time with an international crew.

R.B.

### A89-40485#

#### INTERNATIONAL COOPERATION IN SPACE

ERIC J. LERNER (Aerospace America (ISSN 0740-722X), vol. 27, June 1989, p. 32-34, 36, 38, 39, 43.

Copyright

Recent developments in Soviet-American cooperation in space exploration are reviewed, and prospects for future multilateral cooperation in such activities are considered. The advantages and risks of such cooperation are examined. Current U.S.-Soviet joint projects in space science are listed.

C.D.

### A89-43820

#### THE INTERGOVERNMENTAL SPACE STATION AGREEMENT AND INTELLECTUAL PROPERTY RIGHTS

R. OOSTERLINCK (ESA, Directorate of Administration, Paris, France) Journal of Space Law, vol. 17, no. 1, 1989, p. 23-36. refs

Copyright

The legal framework governing the cooperative design, development, operation, and utilization of the permanently manned civil Space Station by the USA, ESA members, Japan, and Canada is examined. The legal framework is composed of three agreements: (1) the Intergovernmental Agreement, (2) the Memoranda of Understanding, and (3) the Implementing Arrangements. The objectives and signatories of these agreements are described. The establishment of a multiteritorial definition for intellectual property rights is discussed. Particular attention is given to patent laws and acts of infringement.

I.F.

### A89-45175

#### ANNALS OF AIR AND SPACE LAW. VOLUME 13

NICOLAS MATEESCO MATTE, ED. (McGill University, Montreal, Canada) Montreal, McGill University, 1988, 429 p. In English and French. No individual items are abstracted in this volume.

Papers are presented on the obsolescence of bilateral air transport agreements, air transport deregulation in jurisdictions other than the U.S., the role of the ICAO in the suppression of drug trafficking, and aircraft accidents in Japan. Also considered are legal aspects of space conquest, liability for damage caused in outer space by space refuse, international organizations for space regulation, and key judicial decisions related to space law. Other topics include space surveillance for arms control and verification, the extraterritorial application of U.S. antitrust laws, ESA resolutions on participation in the Space Station program, and an international agreement on the establishment of tariffs for intra-European scheduled air services.

R.R.

### A89-45737

#### LUNAR CEMENTS/CONCRETES FOR ORBITAL STRUCTURES

WILLIAM N. AGOSTO (Lunar Industries, Inc., Houston, TX), JOHN H. WICKMAN, and ERIC JAMES (Wickman Spacecraft and Propulsion Co., Citrus Heights, CA) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 157-168. refs

Copyright

It is noted that the lunar surface is an abundant source of inorganic building materials for large space structures. It is

suggested that lunar anorthosites can be processed into calcium aluminate cements in high-temperature high-vacuum solar furnaces on the lunar surface; and there are abundant sources for concrete aggregate in lunar soils and basalts as well as glasses, metals, and ceramics that can be derived from lunar surface materials. The development of new technologies for the mixing and emplacement of lunar cementitious materials and concrete on orbit is discussed. B.J.

#### AB8-45738

##### CONCRETE HABITABLE STRUCTURE ON THE MOON

HARUYUKI NAMBA, TETSUJI YOSHIDA, SHINJI MATSUMOTO, KUNIHICO SUGIHARA, and YOSHIRO KAI (Shimizu Corp., Tokyo, Japan) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 178-189.

Copyright

This paper presents construction methods for a concrete habitable structure on the moon. The study was conducted on the assumption that a concrete manufacturing plant has already been established on the moon and precast concrete components are produced using lunar materials. The major point of this study is that the module can be disassembled into the frame and panels. This paper discusses the artistic design, structural design, manufacturing plant, and construction. Author

AB8-45789\* NASA Space Station Program Office, Reston, VA.

##### SPACE STATION - NEW VENTURE/OLD PROBLEM

JOHN T. COX (NASA, Program Utilization and Operations Group, Reston, VA) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 783-786.

Copyright

Four key operations-related costs are associated with the Space Station: (1) transportation, (2) data management, (3) sustaining engineering, and (4) integrated logistics. Life cycle cost principles will be utilized by the Space Station Program to assess operating costs associated with any particular design 'improvement' opportunity. Author

#### AB8-45818

##### A NEW APPROACH TO HIGHER EDUCATION ON SPACE

DAVID C. WEBB and JAMES A. VEDDA (North Dakota, University, Grand Forks) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 1125-1131.

Copyright

Many universities around the country offer various types of space-related programs at undergraduate and graduate levels. These tend to be narrowly focused on space science or aerospace engineering. While this kind of specialized training is essential, the all-encompassing nature of space development also requires people who possess a broader background that links policy, business, and technology. A new program at the University of North Dakota (UND) aims to train this vital segment of the space community. Author

#### AB8-45820

##### EDUCATION FOR SPACE FACILITIES ENGINEERING

PETER J. TORVIK (USAF, Institute of Technology, Wright-Patterson AFB, OH) IN: Engineering, construction, and operations in space; Proceedings of the Space '88 Conference, Albuquerque, NM, Aug. 29-31, 1988. New York, American Society of Civil Engineers, 1988, p. 1141-1152.

Copyright

The Air Force Institute of Technology, located at Wright-Patterson Air Force Base, Ohio, contains a fully accredited graduate school of engineering which has the mission of meeting Air Force educational requirements in engineering and the physical and managerial sciences and of conducting research in these

areas. Recently, Headquarters USAF requested the school to develop a program designed to prepare officers from the Civil Engineering career field for positions in the development of space facilities. This paper describes the process undertaken and the resulting curriculum. Author

#### AB8-47727

##### A RETURN TO THE MOON

Ad Astra (ISSN 1041-102X), vol. 1, July-Aug. 1989, p. 40-45.

Copyright

This is a National Space Society position paper on the return to the moon. The Society believes that a permanent lunar settlement, and the development and use of moon resources should be an appropriate goal for the U.S. after the Space Station program. The technologies, resources, and experience derived from the lunar effort are crucial to further human expansion into the solar system, including future expeditions. One of the legacies of the Apollo program is the working knowledge of the types of resources available on the moon. Lunar soil contains large amounts of oxygen, silicon and aluminum; iron, helium, and other materials are also available. A strong effort should be made to find out if water ice exists on the moon. A central purpose of using lunar resources is to reduce the cost of space exploration and development. Lunar exploration is in the long term the most effective way to explore and develop the entire solar system for the benefit of mankind. It is concluded that the U.S. should begin a program for a permanent return to the moon in the 1990s after the establishment of the Space Station. C.E.

#### AB8-48144

##### THE SPACE SHUTTLE - A CASE OF SUBJECTIVE ENGINEERING

TRUDY E. BELL and KARL ESCH IEEE Spectrum (ISSN 0018-9235), vol. 26, June 1989, p. 42-46.

Copyright

NASA's approach to risk management, which until the Challenger accident focused on design-oriented techniques rather than probabilistic risk analysis (PRA), is discussed. Political factors that have played a large role in shaping NASA's decisions, along with its traditional-engineering-based corporate culture, are examined. NASA's present experiments with PRA, which are hampered by lack of statistical data, are described. Implications for the Space Station are considered. I.E.

#### AB8-48730

##### LEGAL FRAMEWORK OF THE INTERNATIONAL SPACE STATION COOPERATION

J. REIFARTH (BMFT, Bonn, Federal Republic of Germany) (ESA, Ministry for Science and Technology of Italy, and BMFT, Columbus Symposium, 4th, Friedrichshafen, Federal Republic of Germany, Sept. 12-15, 1988) Space Technology - Industrial and Commercial Applications (ISSN 0892-8270), vol. 9, no. 1-2, 1989, p. 185-188.

Copyright

The legal agreement among the governments cooperating in the Space Station is discussed. The history of the negotiations, the hierarchy of the legal instruments, and the negotiating principles are reviewed. The issues of space treaties, jurisdiction, control, criminal jurisdiction, and intellectual property are addressed. Liability provisions, consultations, and arbitration, and entry into force are considered. C.D.

#### AB8-48825

##### BEHAVIOURAL SCIENCE AND OUTER SPACE RESEARCH

A. J. W. TAYLOR (Wellington, Victoria University, New Zealand) Aviation, Space, and Environmental Medicine (ISSN 0095-6562), vol. 60, Aug. 1989, p. 815, 816. refs

Copyright

This paper notes the awakening interest of NASA in the potential inclusion of behavioral scientists in the U.S. space program, but expresses the fear that unless a major shift occurs in the attitudes of some key personnel the outcome might not be as promising as otherwise possible. It mentions the complete neglect of psychological research in the Skylab studies, and, drawing from

the analogous Antarctic situation of small group isolation, suggests a way in which leeway could be made ready for the pending long-duration and Space-Station projects. Author

#### ABR-48851

##### COLLOQUIUM ON THE LAW OF OUTER SPACE, 31ST, BANGALORE, INDIA, OCT. 13, 14, 1988, PROCEEDINGS

Colloquium sponsored by IAF. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, 384 p. For individual items see ABR-48852 to ABR-48880.

Copyright

Papers in space law are presented, covering topics such as the legal aspects of maintaining space for peaceful purposes, keep-out zones and the nonappropriation principle, verification of outer space treaties, environmental space law, averting space militarization, the arms race in space, and the question of using space stations for military purposes. Other topics include the impact of remote sensing on developing countries, space law problems for developing countries, prospects for a Latin American space agency, UN resolution 41/65, accidents and breaches of contract in outer space, nuclear energy in space, regulating space refuse, aerospace transportation, legal issues of international cooperative Mars missions, the legal implications of space stations, and the protection of the ozone layer. In addition, papers are given on the aerospace plane, international direct television broadcasting, the Antarctic treaty systems as a model for space law, space business contracts, and the regulation of commercial space activities.

R.B.

#### ABR-48855#

##### ENVIRONMENTAL LAW ASPECTS OF MAINTAINING OUTER SPACE FOR PEACEFUL PURPOSES

DAVID ENRICO REIBEL (Institute for Security and Cooperation in Outer Space, Washington, DC) IN: Colloquium on the Law of Outer Space, 31st, Bangalore, India, Oct. 13, 14, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 61-69. refs

Copyright

Consideration is given to the role of international and domestic environmental law in the maintenance of outer space for peaceful purposes. Legal question concerning the possible impact of an arms race in space on nonmilitary spacecraft and on the outer space environment are discussed. The environmental aspects of the 1967 Outer Space Treaty, the 1977 Environmental Modification Convention, and the U.S. National Environmental Policy Act of 1969 as amended are examined, focusing on the application of these laws to a space arms race. Also, the problems of orbital debris, nuclear power sources, radiation phenomena, GEO, and commercial space activities are noted.

R.B.

#### ABR-48856#

##### THE PERMISSIBILITY OR NON-PERMISSIBILITY OF MILITARY USES OF SPACE STATIONS?

JERZY RZYMANEK (Warszawa, Uniwersytet, Warsaw, Poland) IN: Colloquium on the Law of Outer Space, 31st, Bangalore, India, Oct. 13, 14, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 70-73.

Copyright

Legal restrictions on the use of space station for military purposes are discussed. The term 'space station' is defined and the legal status of space stations in outer space and on celestial bodies is outlined. It is found that the use of a space station for deploying nuclear weapons or mass destruction weapons, utilizing environmental modification technology, or testing nuclear weapons or conducting nuclear explosions is prohibited by current space law. It is concluded that, aside from the restrictions, most nonaggressive military uses of outer space are permissible.

R.B.

#### ABR-48863#

##### WHAT SPACE LAW WILL GOVERN ACCIDENTS AND BREACHES OF CONTRACT IN OUTER SPACE?

LELAND G. DRIBIN IN: Colloquium on the Law of Outer Space, 31st, Bangalore, India, Oct. 13, 14, 1988, Proceedings. Washington,

DC, American Institute of Aeronautics and Astronautics, 1989, p. 165-171. refs

Copyright

Consideration is given to the question of what body of law will be applied to resolve disputes between contracting parties arising out of launch mishaps or involving innocent third parties in the U.S. The applicable treaties, statutes, regulations, legal precedents, and court decisions are examined. Tort liability to third parties, product liability, and possible cases involving the government are discussed.

R.B.

#### ABR-48865#

##### THE LEGAL REGIME OF THE U.S. SPACE STATION

KENNETH F. SCHWETJE (USAF, International Law Div., Washington, DC) IN: Colloquium on the Law of Outer Space, 31st, Bangalore, India, Oct. 13, 14, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 179-188.

Copyright

The United States, Japan, Canada, and the European Space Agency have entered into a novel cooperative agreement to build and man a permanent Space Station in the next decade. One of the most important parts of this agreement deals with the legal relationship among the partners. This article describes the overall structure of the Inter-Governmental Agreement. Particular attention is devoted to those articles addressing legal issues. The paper ends with a brief analysis of what this document contributes to space law. An appendix to the paper contains selected articles of the agreement.

Author

#### ABR-48867#

##### THE USE OF NUCLEAR SOURCES OF ENERGY IN OUTER SPACE AND CERTAIN LEGAL ECOLOGICAL ISSUES

ANGEL ANASTASOV (Bulgarian Academy of Sciences, Institute of International Relations and Socialist Integration, Sofia, Bulgaria) IN: Colloquium on the Law of Outer Space, 31st, Bangalore, India, Oct. 13, 14, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 208-211. refs

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The principles and sources of international law relevant to the use of nuclear power sources in outer space are discussed. The safety measures of the UN Committee on Peaceful Uses of Outer Space (1978) are noted. The importance of notification of the return of a nuclear power source from outer space and the possibility of radiological threat is examined. It is suggested that a workable legal regime concerning nuclear power sources must be developed in order to guarantee safety of human life and ecological balance.

R.B.

#### ABR-48868#

##### APPLICATION OF TREATY LAW TO THE REGULATION OF SPACE REFUSE

HOWARD A. BAKER (McGill University, Montreal, Canada) IN: Colloquium on the Law of Outer Space, 31st, Bangalore, India, Oct. 13, 14, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 212-221. refs

Copyright

Space debris poses a variety of hazards to the space activities of mankind and to the integrity of the outer space environment. If present trends continue, it will not be safe to carry out activities in certain sectors of outer space. Several treaty principles to protect the outer space environment and, hence, to control space debris could be invoked. However, any regulation of space debris afforded by these principles is by inference at best. A regime for the effective and efficient control of space refuse is proposed.

Author

#### ABR-48869#

##### SPACE LAW AND PROBLEMS OF AEROSPACE TRANSPORTATION

S. BHATT (Department of Civil Aviation, New Delhi, India) IN: Colloquium on the Law of Outer Space, 31st, Bangalore, India,



Oct. 13, 14, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 222-224. refs  
Copyright

Space law issues related to aerospace transportation are examined. Changes in the Chicago Convention to include aerospace transportation, problems associated with airports and transportation facilities, and the need for combined search and rescue facilities for aviation and space activities are discussed. Consideration is given to liability in space transportation, the Warsaw Convention on liability, and organizational and institutional control of aerospace transportation. Recommendations are made for the development of future space laws. R.B.

#### AB9-48871#

##### INTERNATIONAL COOPERATIVE MISSIONS TO MARS - SOME LEGAL CONSIDERATIONS

JOANN C. CLAYTON (U.S. National Research Council, Washington, DC) IN: Colloquium on the Law of Outer Space, 31st, Bangalore, India, Oct. 13, 14, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 243-249. refs  
Copyright

The legal aspects of international cooperative interplanetary missions and legal issues related to governing extraterrestrial settlements are examined. The relevance of existing space law to Mars missions is reviewed, including the Outer Space Treaty of 1967, the Agreement on the Rescue and Return of Astronauts and Space Objects, the Convention on the Registration of Objects Launched into Outer Space, the convention on International Liability for Damage Caused by Space Objects, and the Agreement Governing Activities of States on the Moon and other Celestial Bodies. Cooperative space programs such as Apollo-Soyuz, the Space Station, Spacelab, Intelsat, and Inmarsat are discussed as precedents for Mars missions. Also, consideration is given to the application of the Antarctic Treaty to planetary settlements. R.B.

#### AB9-48872#

##### SPACE STATIONS AND THEIR LEGAL IMPLICATIONS

I. H. PH. DIEDERIKS-VERSCHOOR IN: Colloquium on the Law of Outer Space, 31st, Bangalore, India, Oct. 13, 14, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 262-267. refs  
Copyright

Legal issues concerning space stations are examined. The characteristics and functions of a space station are defined. Consideration is given to liability in connection with space station activities, legal problems involved with cooperation between states and other participants, and jurisdiction and the settlement of disputes on a space station. The relevance of existing space law to space stations is discussed and suggestions are made for developing new laws to deal with space station issues. R.B.

#### AB9-48876#

##### SOME ISSUES OF THE NEXT PROGRESSIVE DEVELOPMENT OF INTERNATIONAL SPACE LAW

VLADIMIR KOPAL (UN, Outer Space Affairs Div., New York) IN: Colloquium on the Law of Outer Space, 31st, Bangalore, India, Oct. 13, 14, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 297-303. refs  
Copyright

The historical development of international space law and the prospects for future developments are discussed. The treaties between states and UN treaties concerning space law are reviewed. The role of the UN Committee on the Peaceful Uses of Outer Space is considered. The possibility of expanding the juridical content of the fundamental principle of the 1967 Outer Space Treaty is examined. R.B.

#### AB9-48894

##### REFURBISHABLE SATELLITES FOR LOW COST COMMUNICATIONS SYSTEMS

MICHAEL R. HELTON (Contel ASC, McLean, VA) Space Communication and Broadcasting (ISSN 0167-9368), vol. 6, June

1989, p. 379-385.

Copyright

The entry of the Space Station era in the mid-1990s will present an opportunity to significantly reduce the cost of communication services provided by commercial satellites. An operational shuttle, a Space Station, and a reusable geosynchronous transfer capability would open the opportunity for refurbishable satellites. This paper describes a phased approach to the concept and shows how refurbishable satellites would extend communication services for 1/5 to 1/10 the cost of replacement. This concept could also lead to comprehensive unmanned GEO platform containing many other refurbishable services. Author

#### AB9-49373

##### CITIES ON THE MOON - A LOST VISION?

R. C. PARKINSON Spaceflight (ISSN 0038-6340), vol. 31, July 1989, p. 220-223.  
Copyright

The early vision of the moon, in which people would be born, live, work, and die, is reviewed. It is noted that today there are few plans to return to the moon, or, in particular to build permanent bases, colonies, and industries on its surface. With restricted development budgets, and successive decisions made in the Space Shuttle design, the path of low cost space transportation has proven to be more and more difficult. It is concluded that one of the messages that must be gotten across to the decision makers is that space does not have to be an arena for large and expensive projects but needs more and more efforts to make access cheaper. C.E.

#### AB9-49432#

##### NASA/USRA ADVANCED ENGINEERING DESIGN PROGRAM

JOHN ALRED and CAROL HOPF (Universities Space Research Association, Columbia, MD) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989, 5 p.  
(AIAA PAPER 89-2063)

The NASA/USRA University Advanced Design Program is a unique program that brings together NASA engineers, students, and faculty from United States engineering schools by integrating current and future NASA space/aeronautics engineering design projects into the university curriculum. The study topics cover a broad range of potential space and aeronautics projects which could be undertaken during a 20-30 year period beginning with the deployment of Space Station Freedom scheduled for the mid-1990s. Both manned and unmanned endeavors are embraced, and the systems approach to the design problem is emphasized. Author

#### AB9-53627

##### THE MOON, AFTER 20 YEARS AND IN 20 YEARS [LA LUNE, 20 ANS DEJA ET DANS 20 ANS]

BENOIT ROUSSEAU L'Astronomie (ISSN 0004-6302), July-Sept. 1989, p. 352-364. In French. refs  
Copyright

The Apollo program and future plans to return to the moon are discussed. The four pre-lunar missions, Apollo 7, 8, 9, and 10, validated the ability to orbit the moon, the ability to perform EVA, and the functioning of the Command Module and Lunar Module. The Saturn 5 launcher used during the first moon landing mission, Apollo 11, has a thrust of 40,000,000 N. Moon samples were collected during the Apollo 15, 16, and 17 missions using the Lunar Rover. A plan to develop a research and exploration base on the moon in order to study the natural resources of the moon and man's adaptation to extraterrestrial environments is discussed. The lunar base plan involves exploration of the moon using robots and sensors (during the 1990s), the habitation of the moon for periods of weeks by astronauts flown from the International Space Station (2000-2005), and the establishment of a permanent 'city' on the moon capable of accommodating 30 persons (2005-2010). R.R.

## 21 GENERAL

**N89-20873#** Committee on Commerce, Science, and Transportation (U.S. Senate).

### **NASA AUTHORIZATION**

1988 103 p Hearing before the Subcommittee on Science, Technology and Space of the Committee on Commerce, Science and Transportation, 100th Congress, 2d session, part 1 (S-HRG-100-572; GPO-83-952) Avail: Subcommittee on Science, Technology and Space, Senate, Washington, DC 20510 HC free

Hearings before the Science, Technology, and Space Subcommittee of the Senate are presented. The scope and direction, the health and well-being of the nation's Space and Technology Program are discussed. All written testimony and submittals for the record are included. B.G.

**N89-21031#** Lawrence Livermore National Lab., CA.

### **INITIATIVE FOR THE 21ST CENTURY: ADVANCED SPACE POWER AND PROPULSION BASED ON LASERS**

B. G. LOGAN 1 Feb. 1989 25 p Presented at the Initiative for the 21st Century: Advanced Space Power and Propulsion Based on Lasers, Cleveland, OH, 25 Apr. 1988 (Contract W-7405-ENG-48) (DE89-008034; UCRL-98520; CONF-8804249-1) Avail: NTIS HC A03/MF A01

This paper discusses the use of lasers in spacecraft propulsion systems. Cost, efficiencies and comparisons with other propulsion systems are discussed. DOE

**N89-22535#** Committee on Science, Space and Technology (U.S. House).

### **NASA REPORTS REQUIRED BY CONGRESS, 1967-1988**

1989 682 p Presented by the Subcommittee on Space Science and Applications to the Committee on Science, Space and Technology, 100th Congress, 1st Session, May 1989 (GPO-96-193) Avail: Subcommittee on Space Science and Applications, House of Representatives, Washington, DC 20515 HC free; SDO HC \$19.00

Hearings before a subcommittee of the House Committee on Science, Space, and Technology are presented. All written testimony and submittals for the record are also included. Justifications are provided for the Space Station Development Plan and for commercial profit-making space endeavors. B.G.

**N89-24024#** National Academy of Sciences - National Research Council, Washington, DC. Committee on Space Biology and Medicine.

### **A STRATEGY FOR SPACE BIOLOGY AND MEDICAL SCIENCE FOR THE 1990S AND 2000S**

1987 214 p (Contract NASW-3482) (NASA-CR-184895; NAS 1.26:184895) Avail: NTIS HC A10/MF A02 CSCL 06/3

A guideline is provided for developing NASA's long-term mission plans and a rational, coherent research program. Ten topical areas for research are addressed: developmental biology, gravitropism in plants, sensorimotor integration, bone and mineral metabolism, cardiovascular/pulmonary function, muscle remodeling, nutrition, human reproduction, space anemia, and human behavior. Scientific goals, objectives, and required measurements and facilities for each of the major areas of space biology and medicine are identified and described along with primary goals and objectives for each of these disciplines. Proposals are made concerning the use of scientific panels to oversee the implementation of the strategy, life sciences' need for continuous access to spaceflight opportunities, the advantages of a focused mission strategy, certain design features that will enhance spaceflight experimentation, and general facilities. Other topics that are considered include mission planning, crew selection and training, and interagency and international cooperation. A.D.

**N89-24417#** National Aeronautics and Space Administration, Washington, DC.  
**SPACE STATION: A STEP INTO THE FUTURE**

ANDREW J. STOFAN 1989 9 p  
(NASA-PAM-510/11-87; NAS 1.75:510/11-87) Avail: NTIS HC A02/MF A01 CSCL 22/2

The Space Station is an essential element of NASA's ongoing program to recover from the loss of the Challenger and to regain for the United States its position of leadership in space. The Space Station Program has made substantial progress and some of the major efforts undertaken are discussed briefly. A few of the Space Station policies which have shaped the program are reviewed. NASA is dedicated to building a Station that, in serving science, technology, and commerce assured the United States a future in space as exciting and rewarding as the past. In cooperation with partners in the industry and abroad, the intent is to develop a Space Station that is intellectually productive, technically demanding, and genuinely useful. B.G.

**N89-25245#** National Aeronautics and Space Administration, Washington, DC.

### **SPACE STATION OPERATIONS TASK FORCE. PANEL 2 REPORT: GROUND OPERATIONS AND SUPPORT SYSTEMS**

Dec. 1987 569 p  
(NASA-TM-101817; NAS 1.15:101817) Avail: NTIS HC A24/MF A03 CSCL 22/1

The Ground Operations Concept embodied in this report provides for safe multi-user utilization of the Space Station, eases user integration, and gives users autonomy and flexibility. It provides for meaningful multi-national participation while protecting U.S. interests. The concept also supports continued space operations technology development by maintaining NASA expertise and enabling technology evolution. Given attention here are pre/post flight operations, logistics, sustaining engineering/configuration management, transportation services/rescue, and information systems and communication. A.D.

**N89-25246#** National Aeronautics and Space Administration, Washington, DC.

### **SPACE STATION OPERATIONS TASK FORCE. PANEL 3 REPORT: USER DEVELOPMENT AND INTEGRATION**

Dec. 1987 311 p  
(NASA-TM-101818; NAS 1.15:101818) Avail: NTIS HC A14/MF A02 CSCL 22/1

The User Development and Integration Panel of the Space Station Operations Task Force was chartered to develop concepts relating to the operations of the Space Station manned base and the platforms, user accommodation and integration activities. The needs of the user community are addressed in the context with the mature operations phase of the Space Station. Issues addressed include space station pricing options, marketing strategies, payload selection and resource allocation options, and manifesting techniques. A.D.

**N89-25247#** National Aeronautics and Space Administration, Washington, DC.

### **SPACE STATION OPERATIONS TASK FORCE. PANEL 4 REPORT: MANAGEMENT INTEGRATION**

Dec. 1987 213 p  
(NASA-TM-101819; NAS 1.15:101819) Avail: NTIS HC A10/MF A02 CSCL 22/1

The Management Integration Panel of the Space Station Operations Task Force was chartered to provide a structure and ground rules for integrating the efforts of the other three panels and to address a number of cross cutting issues that affect all areas of space station operations. Issues addressed include operations concept implementation, alternatives development and integration process, strategic policy issues and options, and program management emphasis areas. A.D.

**N89-25248#** National Aeronautics and Space Administration, Washington, DC.

### **SPACE STATION OPERATIONS TASK FORCE SUMMARY REPORT**

Oct. 1987 203 p Original contains color illustrations

(NASA-TM-101820; NAS 1.15:101820) Avail: NTIS HC A10/MF A02 CSCL 22/1

A companion to the Space Stations Operation Task Force Panels' Reports, this document summarizes all space station program goals, operations, and the characteristics of the expected user community. Strategies for operation and recommendations for implementation are included. A.D.

**N89-25248\*** National Aeronautics and Space Administration, Washington, DC.

**SPACE STATION OPERATIONS TASK FORCE. EXECUTIVE SUMMARY Final Report**

Oct. 1987 23 p Original contains color illustrations

(NASA-TM-101780; NAS 1.15:101780) Avail: NTIS HC A03/MF A01 CSCL 22/1

The space station program goals, operations and the characteristics of the expected user community are summarized. Strategies for operations and recommendations for implementation are included. A.D.

**N89-26638\*** State Univ. of New York, Albany. Research Foundation.

**QUALITATIVE RESULTS FOR DISTRIBUTED SYSTEMS Final Scientific Report, 1 Jul. 1985 - 30 Jun. 1988**

DANIEL J. INMAN 4 Oct. 1988 10 p

(Contract AF-AFOSR-85-0220-85; AF PROJ. 2304)

(AD-A207005; AFOSR-89-0426TR) Avail: NTIS HC A02/MF A01 CSCL 12/4

This document summarizes the research accomplished under the support of AFOSR-85-0220 from the period of July 1, 1985 to June 30, 1988. Results obtained during this period under AFOSR support are briefly described in the first section. This section is followed by listings of books published, papers published, proceedings published, degrees granted and lectures given while the PI was under Air Force Support. Several results were obtained under the support of this grant which related to the distributed parameter, or partial differential equation, model of a flexible structure. The global model forming the thrust of this research is given by a set of partial differential equations defined on some domain omega with the appropriate boundary and initial conditions. GRA

**N89-26873\*** National Aeronautics and Space Administration, Washington, DC.

**THE BEST WE CAN BE**

1989 28 p

(NASA-TM-101781; NAS 1.15:101781) Avail: NTIS HC A03/MF A01; SOD HC \$2.00 as 033-000-01037-1 CSCL 22/1

A brief history of the U.S. manned space program is presented covering the early Mercury and Gemini missions, the Apollo lunar missions, the Skylab project, and the Space Shuttle missions. The role of the Space Station in future manned missions is also discussed. Descriptions of government centers and major contractors supporting the Space Shuttle program are given. M.G.

**N89-28451\*** Committee on Science and Technology (U.S. House).

**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION MULTIYEAR AUTHORIZATION ACT OF 1989**

Washington GPO 1989 51 p A bill, H.R. 1759, referred to the Committee on Science, Space and Technology, 101st Congress, 1st Session, 10 Apr. 1989

(H-REPT-101-226) Avail: Document Room, House of Representatives, Washington, D.C. 20515 HC free

Hearings before a subcommittee of U.S. House of Representatives are presented to authorize appropriations for the National Aeronautics and Space Administration for the fiscal year 1990. All written testimony and submittals for the record are also included. The budget estimates provide a detailed outline of the budgetary information and justifications for research and development, space flight, control and data communications,

construction of facilities, and research and program management. B.G.

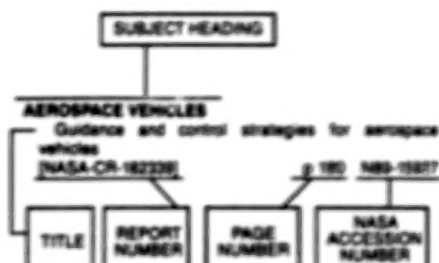
**N89-29273\*** Committee on Appropriations (U.S. House). **DEPARTMENTS OF VETERANS AFFAIRS AND HOUSING AND URBAN DEVELOPMENT AND INDEPENDENT AGENCIES APPROPRIATIONS FOR 1990. PART 6: NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**

1989 169 p Hearings before a Subcommittee of the Committee on Appropriations, 101st Congress, 1st Session, 25 Apr. 1989 (GPC-99-598) Avail: Subcommittee of the Committee on Appropriations, House of Representatives, Washington, D.C. 20510 HC free; SOD HC \$31.00

Hearings before a subcommittee of the House Committee on Appropriations are presented along with budget estimates for the National Aeronautics and Space Administration for the fiscal year 1990. All written testimony and submittals for the record are also included. The budget estimates provide a detailed outline of budgetary information and justifications for research and development, construction of facilities, space flight and communications, and research and program management. B.G.



## Typical Subject Index Listing



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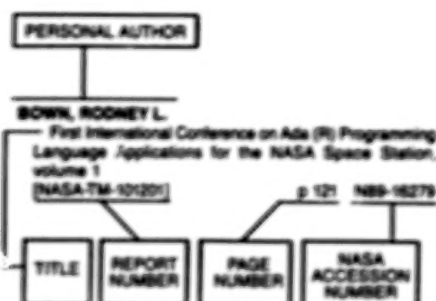
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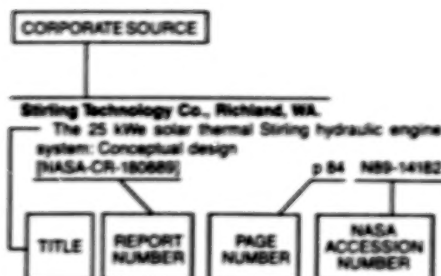
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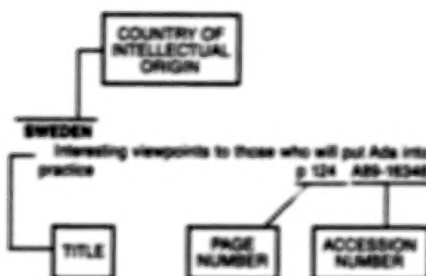
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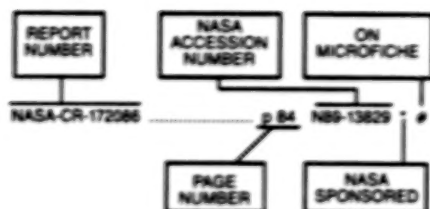
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E-4782	p 85	N88-23527 *	GPO-86-193	p 210	N88-22535 *			
E-4804	p 84	N88-24438 *	GPO-90-598	p 211	N88-28273 *			
E-4808	p 70	N88-26781 *						
E-4807	p 62	N88-22853 *	GPS-REP-SEL-002	p 189	N88-22643 *			
E-4808	p 87	N88-25288 *						
E-4812	p 6	N88-23501 *	H-REPT-101-226	p 211	N88-28451 *			

NAS 1.15-100363	p 36	NBS-24044 *	NAS 1.26-180076	p 23	NBS-24634 *	NASA-CR-172110	p 84	NBS-20182 *
NAS 1.15-100364	p 116	NBS-24421 *	NAS 1.26-181580	p 139	NBS-22780 *	NASA-CR-172112	p 147	NBS-20181 *
NAS 1.15-100367	p 88	NBS-25278 *	NAS 1.26-181746	p 24	NBS-24678 *	NASA-CR-172114	p 86	NBS-24415 *
NAS 1.15-100471	p 154	NBS-22638 *	NAS 1.26-182248	p 30	NBS-26182 *	NASA-CR-177380	p 140	NBS-23512 *
NAS 1.15-100474	p 37	NBS-24790 *	NAS 1.26-182291	p 95	NBS-22138 *	NASA-CR-177495	p 169	NBS-26025 *
NAS 1.15-100615	p 95	NBS-23068 *	NAS 1.26-182293	p 70	NBS-26903 *	NASA-CR-177502	p 39	NBS-25020 *
NAS 1.15-100625	p 85	NBS-24218 *	NAS 1.26-182296	p 6	NBS-23501 *	NASA-CR-179614-VOL-2	p 63	NBS-22981 *
NAS 1.15-101233	p 141	NBS-24505 *	NAS 1.26-182374	p 106	NBS-27204 *	NASA-CR-179614-VOL-3	p 63	NBS-22980 *
NAS 1.15-101245	p 84	NBS-24418 *	NAS 1.26-182379	p 56	NBS-26208 *	NASA-CR-180078	p 23	NBS-24634 *
NAS 1.15-101371	p 141	NBS-26114 *	NAS 1.26-182390	p 118	NBS-26905 *	NASA-CR-181580	p 139	NBS-22780 *
NAS 1.15-101424	p 143	NBS-26885 *	NAS 1.26-182398	p 141	NBS-25353 *	NASA-CR-181746	p 24	NBS-24678 *
NAS 1.15-101448	p 116	NBS-20334 *	NAS 1.26-182495	p 203	NBS-24792 *	NASA-CR-182248	p 30	NBS-26182 *
NAS 1.15-101463	p 203	NBS-24413 *	NAS 1.26-182496	p 203	NBS-24794 *	NASA-CR-182261	p 95	NBS-22138 *
NAS 1.15-101518	p 95	NBS-21824 *	NAS 1.26-183331	p 95	NBS-22622 *	NASA-CR-182263	p 70	NBS-26903 *
NAS 1.15-101548	p 24	NBS-24677 *	NAS 1.26-183551	p 96	NBS-24410 *	NASA-CR-182296	p 6	NBS-23501 *
NAS 1.15-101585	p 23	NBS-24678 *	NAS 1.26-183585	p 110	NBS-21821 *	NASA-CR-182274	p 106	NBS-27204 *
NAS 1.15-101586-VOL-1	p 142	NBS-27687 *	NAS 1.26-183590	p 203	NBS-24793 *	NASA-CR-182279	p 56	NBS-26208 *
NAS 1.15-101594	p 24	NBS-25110 *	NAS 1.26-183597	p 141	NBS-25431 *	NASA-CR-182280	p 118	NBS-26905 *
NAS 1.15-101595	p 22	NBS-23624 *	NAS 1.26-183607	p 94	NBS-24434 *	NASA-CR-182296	p 141	NBS-25353 *
NAS 1.15-101603	p 70	NBS-26886 *	NAS 1.26-183608	p 28	NBS-21023 *	NASA-CR-182495	p 203	NBS-24792 *
NAS 1.15-101623	p 7	NBS-26823 *	NAS 1.26-183615	p 85	NBS-23521 *	NASA-CR-182496	p 203	NBS-24794 *
NAS 1.15-101636	p 25	NBS-27215 *	NAS 1.26-183667	p 170	NBS-26721 *	NASA-CR-183331	p 95	NBS-22622 *
NAS 1.15-101750	p 139	NBS-23483 *	NAS 1.26-183668	p 170	NBS-26722 *	NASA-CR-183551	p 96	NBS-24410 *
NAS 1.15-101780	p 211	NBS-25249 *	NAS 1.26-183669	p 170	NBS-26720 *	NASA-CR-183585	p 110	NBS-21821 *
NAS 1.15-101781	p 211	NBS-26873 *	NAS 1.26-183718	p 142	NBS-26885 *	NASA-CR-183590	p 203	NBS-24793 *
NAS 1.15-101816	p 148	NBS-25244 *	NAS 1.26-184685	p 96	NBS-26454 *	NASA-CR-183597	p 141	NBS-25431 *
NAS 1.15-101817	p 210	NBS-25245 *	NAS 1.26-184686	p 101	NBS-26452 *	NASA-CR-183607	p 64	NBS-24434 *
NAS 1.15-101818	p 210	NBS-25246 *	NAS 1.26-184687	p 103	NBS-26541 *	NASA-CR-183608	p 28	NBS-21023 *
NAS 1.15-101819	p 210	NBS-25247 *	NAS 1.26-184696	p 94	NBS-20175 *	NASA-CR-183615	p 85	NBS-23521 *
NAS 1.15-101820	p 210	NBS-25248 *	NAS 1.26-184697	p 94	NBS-20176 *	NASA-CR-183667	p 170	NBS-26721 *
NAS 1.15-101872	p 106	NBS-26882 *	NAS 1.26-184698	p 94	NBS-20177 *	NASA-CR-183668	p 170	NBS-26722 *
NAS 1.15-101947	p 84	NBS-20179 *	NAS 1.26-184711	p 83	NBS-20173 *	NASA-CR-183669	p 170	NBS-26720 *
NAS 1.15-101961	p 85	NBS-20182 *	NAS 1.26-184712	p 94	NBS-20174 *	NASA-CR-183718	p 142	NBS-26885 *
NAS 1.15-101965	p 162	NBS-21130 *	NAS 1.26-184732	p 2	NBS-20180 *	NASA-CR-184685	p 96	NBS-26454 *
NAS 1.15-101966	p 82	NBS-20194 *	NAS 1.26-184736	p 94	NBS-20481 *	NASA-CR-184686	p 101	NBS-26482 *
NAS 1.15-101971	p 162	NBS-21134 *	NAS 1.26-184796	p 52	NBS-20470 *	NASA-CR-184687	p 103	NBS-26541 *
NAS 1.15-101986	p 111	NBS-23691 *	NAS 1.26-184811	p 56	NBS-26022 *	NASA-CR-184696	p 84	NBS-20175 *
NAS 1.15-102006	p 147	NBS-20171 *	NAS 1.26-184827	p 94	NBS-20183 *	NASA-CR-184697	p 84	NBS-20176 *
NAS 1.15-102015	p 83	NBS-23367 *	NAS 1.26-184828	p 94	NBS-20184 *	NASA-CR-184698	p 94	NBS-20177 *
NAS 1.15-102016	p 83	NBS-23516 *	NAS 1.26-184841	p 20	NBS-21840 *	NASA-CR-184711	p 83	NBS-20173 *
NAS 1.15-102017	p 89	NBS-26041 *	NAS 1.26-184852	p 20	NBS-20152 *	NASA-CR-184712	p 84	NBS-20174 *
NAS 1.15-102018	p 116	NBS-23517 *	NAS 1.26-184867	p 52	NBS-20151 *	NASA-CR-184732	p 2	NBS-20180 *
NAS 1.15-102020	p 82	NBS-23681 *	NAS 1.26-184895	p 210	NBS-24024 *	NASA-CR-184736	p 94	NBS-20481 *
NAS 1.15-102044	p 85	NBS-23527 *	NAS 1.26-184913	p 142	NBS-26541 *	NASA-CR-184796	p 52	NBS-20470 *
NAS 1.15-102052	p 84	NBS-24438 *	NAS 1.26-185117	p 71	NBS-27296 *	NASA-CR-184811	p 56	NBS-26022 *
NAS 1.15-102054	p 82	NBS-22683 *	NAS 1.26-185324	p 96	NBS-25638 *	NASA-CR-184827	p 84	NBS-20183 *
NAS 1.15-102055	p 87	NBS-25289 *	NAS 1.26-185326	p 37	NBS-25981 *	NASA-CR-184828	p 94	NBS-20184 *
NAS 1.15-102056	p 86	NBS-25282 *	NAS 1.26-185330	p 69	NBS-26042 *	NASA-CR-184841	p 20	NBS-21840 *
NAS 1.15-102062	p 89	NBS-26177 *	NAS 1.26-185361	p 96	NBS-26032 *	NASA-CR-184852	p 20	NBS-20152 *
NAS 1.15-102063	p 86	NBS-25506 *	NAS 1.26-185371	p 142	NBS-26537 *	NASA-CR-184867	p 52	NBS-20151 *
NAS 1.15-102064	p 118	NBS-25272 *	NAS 1.26-185383	p 140	NBS-24426 *	NASA-CR-184895	p 210	NBS-24024 *
NAS 1.15-102065	p 86	NBS-26889 *	NAS 1.26-185387	p 96	NBS-25368 *	NASA-CR-184913	p 142	NBS-26541 *
NAS 1.15-102066	p 87	NBS-25287 *	NAS 1.26-185403	p 112	NBS-26430 *	NASA-CR-185117	p 71	NBS-27296 *
NAS 1.15-102072	p 87	NBS-25275 *	NAS 1.26-185409	p 112	NBS-25773 *	NASA-CR-185324	p 96	NBS-25638 *
NAS 1.15-102073	p 87	NBS-25273 *	NAS 1.26-185429	p 105	NBS-26775 *	NASA-CR-185326	p 37	NBS-25981 *
NAS 1.15-102074	p 85	NBS-24439 *	NAS 1.26-185444	p 96	NBS-26017 *	NASA-CR-185330	p 89	NBS-26042 *
NAS 1.15-102076	p 84	NBS-24418 *	NAS 1.26-185452	p 56	NBS-26034 *	NASA-CR-185361	p 56	NBS-26032 *
NAS 1.15-102081	p 29	NBS-24440 *	NAS 1.26-185485	p 69	NBS-26043 *	NASA-CR-185371	p 142	NBS-26537 *
NAS 1.15-102083	p 86	NBS-25280 *	NAS 1.26-185621	p 117	NBS-26486 *	NASA-CR-185383	p 140	NBS-24436 *
NAS 1.15-102085	p 70	NBS-26781 *	NAS 1.26-185627	p 144	NBS-26476 *	NASA-CR-185387	p 96	NBS-25368 *
NAS 1.15-102086	p 189	NBS-25254 *	NAS 1.26-185637	p 184	NBS-25598 *	NASA-CR-185403	p 112	NBS-26430 *
NAS 1.15-102093	p 71	NBS-27705 *	NAS 1.55-10012-PT-3	p 7	NBS-26798 *	NASA-CR-185406	p 112	NBS-25773 *
NAS 1.15-102097	p 30	NBS-25078 *	NAS 1.55-3030	p 85	NBS-24704 *	NASA-CR-185429	p 105	NBS-26775 *
NAS 1.15-102105	p 85	NBS-24448 *	NAS 1.55-3032	p 95	NBS-23992 *	NASA-CR-185444	p 96	NBS-26017 *
NAS 1.15-102117	p 87	NBS-26178 *	NAS 1.55-3033	p 105	NBS-26578 *	NASA-CR-185452	p 56	NBS-26034 *
NAS 1.15-102118	p 87	NBS-25283 *	NAS 1.55-3035-PT-1	p 184	NBS-23528 *	NASA-CR-185485	p 89	NBS-26043 *
NAS 1.15-102131	p 70	NBS-26292 *	NAS 1.55-3035-PT-2	p 110	NBS-23547 *	NASA-CR-185621	p 117	NBS-26486 *
NAS 1.15-102135	p 86	NBS-24444 *	NAS 1.55-3043	p 87	NBS-26184 *	NASA-CR-185837	p 144	NBS-26476 *
NAS 1.15-102136	p 84	NBS-24427 *	NAS 1.71-LAR-14149-1-58	p 3	NBS-26547 *	NASA-CR-98223(25)	p 184	NBS-25598 *
NAS 1.15-102139	p 72	NBS-29484 *	NAS 1.71-MFS-28327-1	p 33	NBS-26556 *			
NAS 1.15-102141	p 86	NBS-25403 *	NAS 1.71-MSC-21380-1	p 55	NBS-25283 *	NASA-NP-106	p 189	NBS-25818 *
NAS 1.15-102154	p 184	NBS-22682 *	NAS 1.71-MSC-21386-1	p 3	NBS-26552 *	NASA-PAM-510/11-87	p 210	NBS-24417 *
NAS 1.15-102204	p 37	NBS-26388 *	NAS 1.75-510/11-87	p 210	NBS-24417 *			
NAS 1.15-102281	p 117	NBS-21026 *	NAS 1.83-106	p 189	NBS-25818 *	NASA-SF-7048(30)	p 3	NBS-26037 *
NAS 1.15-102283	p 89	NBS-26045 *						
NAS 1.15-102286	p 87	NBS-26036 *	NASA-CASE-ARC-11505-2	p 3	NBS-25286 *	NASA-TM-100358	p 183	NBS-21246 *
NAS 1.15-102287	p 170	NBS-26035 *				NASA-TM-100362	p 36	NBS-23503 *
NAS 1.15-102297	p 70	NBS-26887 *	NASA-CASE-GSC-13112-1	p 89	NBS-29578 *	NASA-TM-100363	p 36	NBS-24044 *
NAS 1.15-102298	p 87	NBS-26878 *				NASA-TM-100364	p 118	NBS-24421 *
NAS 1.15-102303	p 87	NBS-26844 *	NASA-CASE-LAR-13786-1	p 75	NBS-25363 *	NASA-TM-100367	p 86	NBS-25278 *
NAS 1.15-102306	p 89	NBS-26835 *	NASA-CASE-LAR-14149-1-58	p 3	NBS-26547 *	NASA-TM-100471	p 184	NBS-22638 *
NAS 1.15-102321	p 86	NBS-26804 *				NASA-TM-100474	p 37	NBS-24790 *
NAS 1.15-102335	p 71	NBS-27702 *	NASA-CASE-MFS-28327-1	p 33	NBS-28958 *	NASA-TM-100615	p 95	NBS-23088 *
NAS 1.15-102339	p 118	NBS-26570 *				NASA-TM-100625	p 85	NBS-24218 *
NAS 1.15-102347	p 71	NBS-27704 *	NASA-CASE-MSC-21117-2	p 142	NBS-28954 *	NASA-TM-101233	p 141	NBS-24505 *
NAS 1.15-4073	p 75	NBS-26850 *	NASA-CASE-MSC-21211-1	p 3	NBS-26953 *	NASA-TM-101245	p 84	NBS-24418 *
NAS 1.15-89445	p 142	NBS-26304 *	NASA-CASE-MSC-21380-1	p 55	NBS-25283 *	NASA-TM-101371	p 141	NBS-26114 *
NAS 1.21-7048(20)	p 3	NBS-26037 *	NASA-CASE-MSC-21386-1	p 3	NBS-26952 *	NASA-TM-101434	p 143	NBS-26885 *
NAS 1.26-172110	p 84	NBS-20182 *				NASA-TM-101434	p 118	NBS-25024 *
NAS 1.26-172112	p 147	NBS-20181 *	NASA-CF-10012-PT-3	p 7	NBS-25789 *	NASA-TM-101483	p 203	NBS-24413 *
NAS 1.26-172114	p 86	NBS-24415 *	NASA-CF-3030	p 85	NBS-24704 *	NASA-TM-101518	p 85	NBS-21824 *
NAS 1.26-177380	p 140	NBS-23612 *	NASA-CF-3032	p 95	NBS-23982 *	NASA-TM-101548	p 24	NBS-24677 *
NAS 1.26-177495	p 189	NBS-26025 *	NASA-CF-3033	p 105	NBS-26578 *	NASA-TM-101585	p 23	NBS-24676 *
NAS 1.26-177502	p 39	NBS-26020 *	NASA-CF-3035-PT-1	p 184	NBS-23528 *	NASA-TM-101586-VOL-1	p 142	NBS-27687 *
NAS 1.26-179614-VOL-2	p 83	NBS-23981 *	NASA-CF-3035-PT-2	p 110	NBS-23547 *	NASA-TM-101594	p 24	NBS-25110 *
NAS 1.26-179614-VOL-3	p 83	NBS-22980 *	NASA-CF-3043	p 87	NBS-26184 *			

NASA-TM-101595	p 22	NBS-23924 *	#	PSBS-15802	p 171	NBS-27807	#	US-PATENT-APPL-SN-361200	p 30	NBS-28558 *	#
NASA-TM-101603	p 70	NBS-26886 *	#	PyM-88-06	p 162	NBS-21015	#	US-PATENT-APPL-SN-825675	p 142	NBS-28554 *	#
NASA-TM-101623	p 7	NBS-26623 *	#	PNL-SA-15871	p 29	NBS-21639	#	US-PATENT-CLASS-185-32	p 30	NBS-29038	#
NASA-TM-101636	p 25	NBS-27215 *	#	PNL-SA-16305	p 29	NBS-22060	#	US-PATENT-CLASS-206-0.7	p 89	NBS-29578 *	#
NASA-TM-101750	p 139	NBS-23493 *	#	PNL-SA-16952	p 25	NBS-28861	#	US-PATENT-CLASS-220-5A	p 89	NBS-29578 *	#
NASA-TM-101780	p 211	NBS-25249 *	#	PSDB-100017	p 74	NBS-22648	#	US-PATENT-CLASS-220-901	p 89	NBS-29578 *	#
NASA-TM-101781	p 211	NBS-26873 *	#	R/D-5647-MS-01.4	p 2	NBS-21090	#	US-PATENT-CLASS-244-159	p 3	NBS-25296 *	#
NASA-TM-101816	p 148	NBS-25244 *	#	REPT-1	p 84	NBS-20175 *	#	US-PATENT-CLASS-244-161	p 3	NBS-25296 *	#
NASA-TM-101817	p 210	NBS-25245 *	#	REPT-2	p 84	NBS-20176 *	#	US-PATENT-CLASS-244-181	p 3	NBS-25296 *	#
NASA-TM-101818	p 210	NBS-25246 *	#	REPT-34/88	p 190	NBS-23980	#	US-PATENT-CLASS-248-DIG-1	p 142	NBS-28554 *	#
NASA-TM-101819	p 210	NBS-25247 *	#	REPT-3	p 84	NBS-20177 *	#	US-PATENT-CLASS-285-226	p 3	NBS-28553 *	#
NASA-TM-101820	p 210	NBS-25248 *	#	REPT-471126/1/FR	p 189	NBS-22901	#	US-PATENT-CLASS-285-302	p 3	NBS-25296 *	#
NASA-TM-101872	p 106	NBS-29982 *	#	REPT-482-430-109	p 22	NBS-23506	#	US-PATENT-CLASS-343-DIG.2	p 75	NBS-25363 *	#
NASA-TM-101947	p 84	NBS-20179 *	#	REPT-482-430-110	p 190	NBS-23509	#	US-PATENT-CLASS-343-880	p 75	NBS-25363 *	#
NASA-TM-101951	p 85	NBS-20182 *	#	REPT-482-440-102	p 85	NBS-23645	#	US-PATENT-CLASS-343-915	p 75	NBS-25363 *	#
NASA-TM-101955	p 162	NBS-21100 *	#	REPT-482-440-105	p 84	NBS-23679	#	US-PATENT-CLASS-403-30	p 142	NBS-28554 *	#
NASA-TM-101956	p 62	NBS-20194 *	#	REPT-482-440-110	p 190	NBS-23511	#	US-PATENT-CLASS-403-4	p 142	NBS-28554 *	#
NASA-TM-101971	p 162	NBS-21104 *	#	REPT-482-440-115	p 30	NBS-27688	#	US-PATENT-CLASS-403-51	p 3	NBS-28553 *	#
NASA-TM-101986	p 111	NBS-23691 *	#	REPT-482-440-118	p 199	NBS-24050	#	US-PATENT-CLASS-52-573	p 142	NBS-28554 *	#
NASA-TM-102006	p 147	NBS-20171 *	#	REPT-482-440-120	p 85	NBS-24442	#	US-PATENT-CLASS-52-648	p 142	NBS-28554 *	#
NASA-TM-102015	p 63	NBS-23367 *	#	REPT-48900099	p 105	NBS-26578 *	#	US-PATENT-CLASS-62-45	p 89	NBS-29578 *	#
NASA-TM-102016	p 63	NBS-23516 *	#	REPT-49000114	p 87	NBS-26184 *	#	US-PATENT-CLASS-62-48	p 89	NBS-29578 *	#
NASA-TM-102017	p 69	NBS-26041 *	#	RI/ROM-256	p 118	NBS-26805 *	#	US-PATENT-4,805,368	p 142	NBS-28554 *	#
NASA-TM-102019	p 118	NBS-23517 *	#	RI/ROM-154	p 85	NBS-23521 *	#	US-PATENT-4,807,834	p 3	NBS-25296 *	#
NASA-TM-102020	p 62	NBS-22951 *	#	RI/ROM-214-TASK-E.5	p 106	NBS-27304 *	#	US-PATENT-4,808,906	p 3	NBS-28553 *	#
NASA-TM-102044	p 85	NBS-23527 *	#	RIACS-TR-88.13	p 112	NBS-26450 *	#	US-PATENT-4,811,033	p 75	NBS-25363 *	#
NASA-TM-102052	p 4	NBS-24436 *	#	RIACS-TR-88.22	p 112	NBS-25773 *	#	US-PATENT-4,813,476	p 30	NBS-28038	#
NASA-TM-102054	p 3	NBS-22953 *	#	RIACS-TR-88.2	p 105	NBS-26775 *	#	US-PATENT-4,821,907	p 89	NBS-29578 *	#
NASA-TM-102055	p 67	NBS-25269 *	#	RX-880001	p 113	NBS-30126	#	UVA/S25M83/AMM/101	p 54	NBS-21830	#
NASA-TM-102056	p 67	NBS-25269 *	#	S-HRG-100-579	p 210	NBS-20673	#	W/O-11304	p 2	NBS-21021	#
NASA-TM-102059	p 66	NBS-25262 *	#	S-581	p 37	NBS-24790 *	#				
NASA-TM-102062	p 69	NBS-26177 *	#	S-593	p 164	NBS-22662 *	#				
NASA-TM-102063	p 66	NBS-25006 *	#	SAE P-216	p 115	AB-47326	#				
NASA-TM-102064	p 118	NBS-25272 *	#	SAE PAPER M1540	p 145	AB-47327	#				
NASA-TM-102065	p 66	NBS-26895 *	#	SAE PAPER M1542	p 146	AB-47328	#				
NASA-TM-102066	p 67	NBS-25267 *	#	SAND-88-2386C	p 22	NBS-23230	#				
NASA-TM-102072	p 67	NBS-25275 *	#	SAND-88-3081	p 21	NBS-23440	#				
NASA-TM-102073	p 67	NBS-25273 *	#	SAND-88-0181C	p 170	NBS-27089	#				
NASA-TM-102074	p 65	NBS-24439 *	#	SAWE PAPER 1818	p 83	AB-50614 *	#				
NASA-TM-102076	p 84	NBS-24418 *	#	SAWE PAPER 1819	p 17	AB-50615 *	#				
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